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EDITORIAL.

ITEMS AND NOVELTIES.

The Church Street District, Boston, Massachusetts.—An extensive engineering work, in change of grade with raising of buildings, and street widening by moving them, is now in progress at Boston.

To give a proper understanding of the operations, we will state that the present site of the city of Boston was originally four small hills, which in very high tides became islands, but at mean tides were so connected by marshes that the whole became a peninsula, of irregular shape, about three-fourths of a mile in greatest width, and one and three-fourths of a mile long, with a neck about one and a fourth miles long connecting to the main land. From the three higher hills, Copps, Beacon and Fort hills, Boston was called tri-mountain, the fourth, Holles hill, being only a knoll of perhaps twenty-four feet summit elevation above tides. Copps hill was the earliest set-

tled. Its crest has been preserved by a grave-yard and fort (now all grave-yard), and the eastern side of it was, twenty years since, an almost exact miniature copy of the old part of London city, having been built in the same manner and at the same time, (that is, after the great fire at London,) with streets, alleys, styles of construction, in careful similitude to the great city. The past twenty years has demolished these remnants of the seventeenth century more completely than they have been removed in London. So that the old inhabitant of Boston can find Queen Ann street, Moon street, North Square, readily, in London, to-day, while he could hardly find a recollection of these localities at home.

Beacon hill and Fort hill were country residences. The former was encroached upon for city use about the beginning of this century, and the summit, some twenty feet in height, removed; and later, about forty years since, extensive excavations graded the eastern slope. It is yet about sixty to eighty feet elevation at the State House. Fort Hill was also covered with dwelling houses thirty to fifty years since, which have in course of time been isolated from the other dwelling house parts of the city by the increase of warehouses, and have degenerated into tenements for the poorer of the laboring population, mostly Irish.

Now, a cut, eighty feet wide by six hundred feet long, and sixty feet in greatest depth, has ruthlessly opened the narrow lanes and winding ways, and encroached on the aristocratic seclusion of Washington Square, with its circular green (the old Fort), which once gave the most beautiful prospect of the country and harbor. A few years more, and this landmark will disappear.

But to return to our subject. Amongst the improvements of Boston of fifty years ago was a mill dam, about one and a fourth miles long, enclosing some two square miles of tidal basin, or rather two basins, as a cross dam of three-fourths of a mile in length separated the two. One of these basins was intended for high water and the other for low water, and as a constant difference of about six feet could be maintained in the water level of these two basins, it was supposed a very valuable water power would be established.

Alas! Pennsylvania and Pictou coal proved too strong a rival to the water power, and, as a commercial enterprise, it failed. But after many years, the growth of Boston, far exceeding the limits of ground, has brought this property into the market as land, and those speculators or investers who have kept their property in the

Boston Water Power Company now find all their anticipations of returns far more than realized in the value of land for building purposes, or rather in the value of that share of the land which, with the State and other claimants by rights in the shore, has been divided; after thirty feet deep of gravel has been brought by railway, and deposited on four or five square miles of marsh and basin. About one square mile is already filled in.

This filling and extension of the city to the westward has involved the considerations of drainage, level, and grades, which has not been the least of the troubles to provide for.

Along the western and southwestern edge of Holles hill, a street, Pleasant street, was at the time of the Revolution laid out and occupied, and the high tides came up to the back end of the lots on this street. After the formation of the low water basin by the Boston Water Power Company, the level of tidal flow was here depressed some nine to eleven feet, and upon the slope of ground, about nine hundred feet long by six hundred feet wide, were laid out several narrow streets, Church, Marion, Fayette, South Cedar and others, which were built up with small houses, much like those of Southwark, London, or Southwark, Philadelphia. None of the houses rose above three low stories in height, most of them but two, with or without a basement half story. The only large building was a Methodist church, from which Church street derives its name. The streets were none over thirty feet in width, and mostly twenty or twenty-five feet, and some lanes of twelve or sixteen feet. This little tract of territory, consequently, about equal in size to three Philadelphia squares, and having exactly the same number of houses that are placed upon three Philadelphia squares, that is, four hundred and fifty, became, by the raising of the ground beyond it, a sunken spot about twelve feet on the average below the possibility of drainage, with about seventeen and a half feet depression at the lowest point.

After much discussion, the city determined to raise the entire district as a whole, and to take advantage of the disturbances of *immovable* property at the same time, by widening all the narrow streets, so that none should be less than twenty-five or thirty feet between the houses.

Operations were commenced about the first of July last, but it was not until about the first of August that direct work on the district was begun. The number of buildings to be raised—some of them

to be moved, also—was four hundred and fifty, or about that number. The commissioners immediately circumscribed rather more than three-fourths of all the district and placed it under contract. This portion of the district consisted of all south of Church street, and that between Church and Pleasant streets east of Marion street, thus leaving only a comparatively small piece bounded by Church street, Marion street, Pleasant street and Madison place. When fairly begun, the work was pushed with the utmost vigor, and surprising progress was the consequence. The spot chosen for beginning was at the foot of Fayette street, which was the most depressed place on the territory. Here the buildings were soon raised, and the cars, running along the temporary track in Ferdinand street night after night, deposited their loads of gravel, to be shovelled or carried in wheelbarrows under the stilted houses during the day. This was the beginning in the first part of August. Now every building on the division described as being under contract is raised or being raised. The filling has progressed equally well. The tracks of the temporary railroad are laid in Grenville place, Ferdinand street, and Fayette street. All night the trains are running, and the gravel is dumped off at the sides of the embankment in the streets on which the tracks are laid. The number of car loads brought in each night varies between two hundred and two hundred and fifty, and as two car loads make a square of filling (eight cubic yards), from one hundred to one hundred and twenty-five squares are thus added nightly to the territory. In vacant places between Church, Ferdinand, South Cedar and Marion streets, and between Berlin, Shawmut, Church and Pleasant streets, there are now large surplus deposits awaiting the completion of the raising of the buildings surrounding, when the gravel will be spread. As soon as a building is ready, the laborers, who number about one hundred in this department, convey the gravel from the track sides underneath the house, which is soon standing on the new *terra firma*. In this way the work has been done, and the result of about four months' labor is the filling of about one-third of the entire district. The only streets on which no filling has been done are Piedmont and Marion, and these will very soon be reached.

In South Cedar street hand cars are now employed, and it is intended to run the locomotives and trains there presently. It will be readily seen that the progress in future will be much more rapid than that heretofore, in consequence of the increase of the facilities

for employing the gravel trains. At the close of the season, or when further operations will be prevented by the extreme cold weather, three-fourths of the entire work will be completed; and this will have been effected in about five months, and at an expense safely inside the estimates. There have been no serious obstacles, and the course of the commissioners has been unexpectedly smooth. The outlay up to the 1st of November had been $200,000.

About six houses, or one hundred and twenty feet long, are usually raised in one block together, the walls, front and back, being cut, or rather a line of separation being made at about each sixth house. The raising is done by screws, as usual, and the blocking is the usual cob-house work of pieces of timber. The moving is on wooden rollers, round iron bars, and on balls, with no apparent reason for choosing or using either. Of course, those houses at the ends of each block, in raising, where the party wall is removed, are carefully clamped and braced. And about every fourth house has been found to require the front and back walls to be clamped by through bolts to the floors. The walls may be said to be universally but eight inches—one brick thick.

About one-half the houses are occupied, the raising or moving not interfering with the domestic comforts of the household, although it would seem inconvenient to small children to find the doors seventeen feet above ground, and it is possible that the ladies object to the ladder ingress and egress. From an examination of the buildings, very few cracks are discernible, either in those which have been finally underpinned, or in those undergoing the transitions. The ground is fortunately all solid, (not made, as the Boston name goes,) and the underpinning is either done in brick or in cubical granite blocks, which lay without the settlement of what is generally known as rubble masonry.

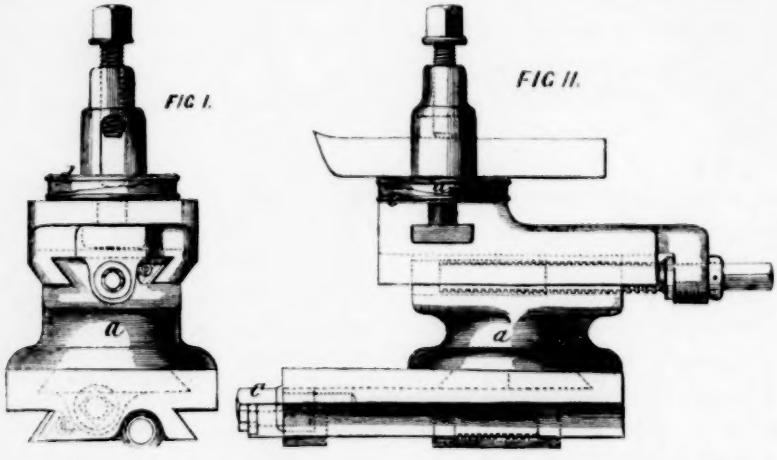
This instance of moving brick edifices has not the extent of area, as a whole, or the magnitude of buildings which the Chicago example presented, but the work going on at one place is large, and the numerous walls, the narrow passages, the height of elevation, and the moving of the houses, makes it, in detail and labor, noteworthy beside that memorable instance of engineering. B.

Tool Rests.—The accompanying illustrations represent various forms of tool rests employed by Messrs. Bement & Dougherty on their lathes.

We will first describe the older form, and then point out the modifications which have been introduced, and are found applicable, with advantage, to many cases, without displacing the other forms which are still largely employed.

Fig. 1 is an end, and Fig. 2 a side elevation of an adjustable rest with compound traverse, which has two noticeable peculiarities, and which has been long in use.

In the first place, the mode of adjusting the tool by means of two case-hardened, wrought iron rings, or circular inclined planes, with milled edges, encircling the tool-post at *d*. By placing the thick edge of one and the thin end of the other together, the upper surface is made horizontal, and by placing the two thick edges together the greatest angle of adjustment is obtained. Between these limits any degree may be got by turning one or both the rings, as the case may require.



The other peculiar feature is the mode of swivelling and clamping the upper portion, *a*, of the rest upon the lower. This is done by a circular, *v*, as shown in dotted lines, having, on one side, a certain portion cut out, into which is fitted a tail-piece, *b*, worked by a set screw, *c*. The effect of this, when clamped tightly by the screw, is to wedge the upper portion, *a*, down hard against the lower one, and thus secure great rigidity.

The new style of construction is shown in Plate I., where Fig. 1 represents an adjustable rest intended for lathes where the ordinary single traverse movement suffices for the requirements of the work.

ADJUSTABLE TOOL REST.

by

Bement & Dougherty,

Industrial Works,

Philadelphia, March 1868.

Fig. 1.

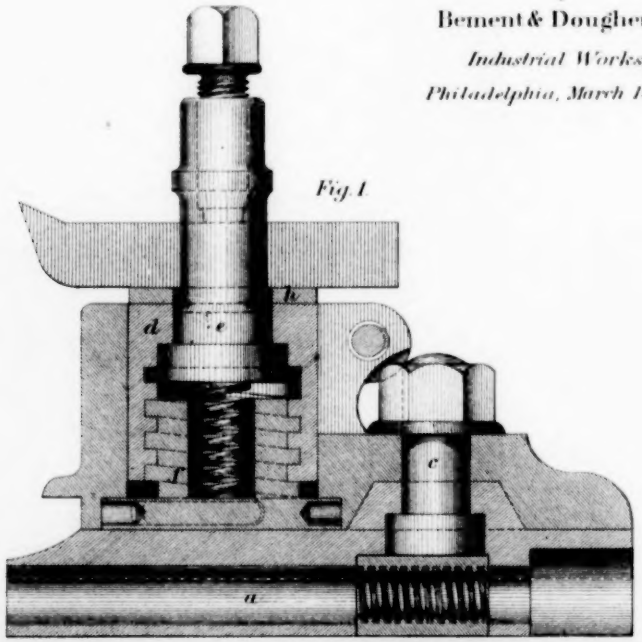
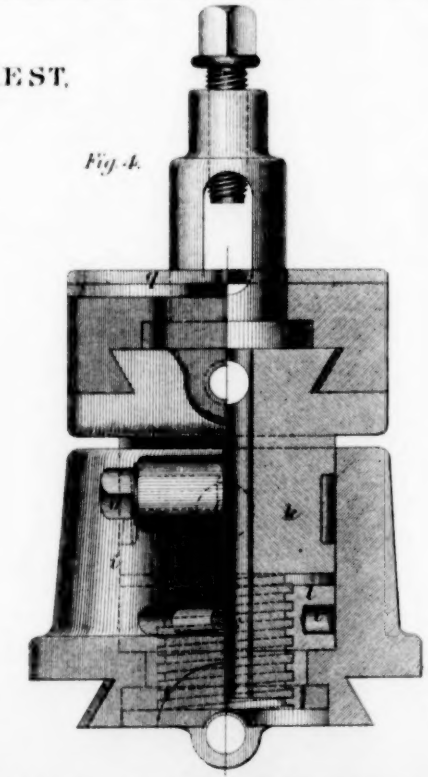


Fig. 4.



Lith. Jas Mc Guigan Phila.a

a is the usual slide worked by a screw in the lathe-carriage; *b* is the main or lower portion of tool rest swivelling round the clamping-bolt, *c*. The tool-post, of the usual shape, is held in a nut, *d*, into which works a screw, *f*, and raises or lowers the nut, *d*, with its tool-holder. This screw is operated by the workman, with a small lever fitting into holes or sockets cut in the screw, as shown in Fig. 1.

A spline and feather in *b* keeps the nut from turning, and a bolt at *i* serves to clamp it in any position.

The advantage of this rest is, that the tool can, with the greatest convenience and accuracy, be raised and lowered after it is screwed up in its holder, or without slacking the set-screw.

Fig. 2, Plate I., shows a half end elevation and half cross-section of the same kind of rest with double traverse for lathes where universal adjustment is required. The upper slide, of the usual construction, has a column, *k*, on its under side, which is clamped into the other portion by the bolt, *o*, in the same manner as in Fig. 1; its lower extremity is a screw, upon which works the nut, *l*, operated by a lever in the manner already described in Fig. 1. This nut is stationary, and being rotated by the lever, raises and lowers the screw on *k*, carrying with it the tool-post and upper slide.

This rest can, with perfect facility and accuracy, be raised and lowered, and also swivelled into any position without unscrewing the tool. A small pin, dotted at *m*, works, by means of a spring, into slots in *k*, shown at *n*, which keep the rest square when it is desired to do so.

At *j* is seen the opening in the outer shell, through which the workman operates with the lever the internal nut or screw.

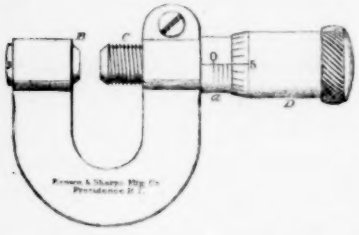
The whole makes a very desirable arrangement where accuracy of adjustment and convenience of working are required.

Pocket Sheet-metal Gauge, by Brown & Sharpe Manufacturing Company. At the last meeting of the Institute there was exhibited a new form of gauge, constructed by the firm above mentioned.

It involves the same essential advantages as are found in the larger sheet-metal gauges manufactured by the same establishment, and before described in this *Journal*. That is to say, it can take its measurement not from the edge of the sheet only (where irregularities are likely to occur), but at some little distance within. It also not only indicates whether the sheet in question does or does

not conform approximately to some one of a series of arbitrary standard measurements, but in every case gives the exact thickness in parts of an inch, reaching down to thousandths.

The accompanying cut shows the instrument of full size, and it may be described as follows:



The piece in the form of the letter U has a projecting hub, *a*, on one end. Through the two ends are tapped holes, in one of which is the adjusting screw, B, and in the other the gauge screw, C. Attached to the screw, C, is a thimble, D, which fits over the exterior of the hub, *a*. The end of this thimble is beveled, and the beveled edge graduated into twenty-five parts, and figured, 0, 5, 10, 15, 20. A line of graduations 40 to the inch is also made upon the outside of the hub, *a*, the line of these divisions running parallel with the centre of the screw, C, while the graduations on the thimble are circular. The pitch of the screw, C, being 40 to the inch, one revolution of the thimble opens the gauge $\frac{1}{40}$ or $\frac{25}{1000}$ of an inch. The divisions on the thimble are then read off for any additional part of a revolution of the thimble, and the number of such divisions are added to the turn or turns already made by the thimble, allowing $\frac{25}{1000}$ for each graduation on the hub, *a*. For example, suppose the thimble to have made four revolutions and one-fifth. It will then be noticed that the beveled edge has passed four of the graduations on the hub, *a*, and opposite the line of graduation will be found on the thimble the line marked 5. Add this number to the amount of the four graduations, which is $\frac{100}{1000}$, and it equals $\frac{105}{1000}$, which is the measurement shown by the gauge.

On the above occasion, Mr. Coleman Sellers mentioned that he had been using one of these gauges for several weeks, and had compared it with other standards by means of the set of tables furnished by the manufacturers, and that this test had proved it to be entirely reliable.

The Hoosac Tunnel.—The work at this tunnel having now reached such a point that all serious difficulties being surmounted, what remains to be done is simply a matter of removing so many yards of rock under fixed conditions, the further prosecution of the structure has been placed under contract to responsible parties, and

Mr. Latrobe, considering the continuance of his office as Consulting Engineer unnecessary, has resigned it.

Electric Exploder, for Blasting, by Charles T. Chester, Esq., of New York.—At the last meeting of the Institute, there was exhibited a very efficient apparatus, devised and constructed by Mr. Chester, for use in connection with mining, tunneling, and other like operations. It consisted of a cylindrical case of hard rubber, 4½ inches in diameter, and 10 inches long, with a crank and handle projecting from one end, as also a small button or knob; while from the other end stood out two rounded binding screws. The charge or percussion fuse being connected with the binding screws by insulated wires, the handle is turned round a dozen or twenty times, and then the button is pulled out about one inch, when a spark passes and fires the fuse.

The interior structure of the apparatus is as follows: At the axis of the cylindrical case is a small cylinder of hard rubber, rotated by the projecting handle. This has on one side a rubber covered with mosaic gold, and on the other a series of points, like an ordinary electrical machine. The rubber is connected with a sheet of tinfoil rolled within the case, and the points with another sheet face to face with the first, but carefully insulated from it. The apparatus is thus both a frictional electrical machine and a leyden jar. When the button is pulled out, two brass strips are caused to connect the binding screws with these two sheets of foil, and a discharge of course occurs through the fuse.

The advantages of this machine are its compactness and certainty. Being entirely enclosed in an insulating case, it is free from all disturbance on account of dampness, and has sufficient force to fire many hundred blasts at once, if required.

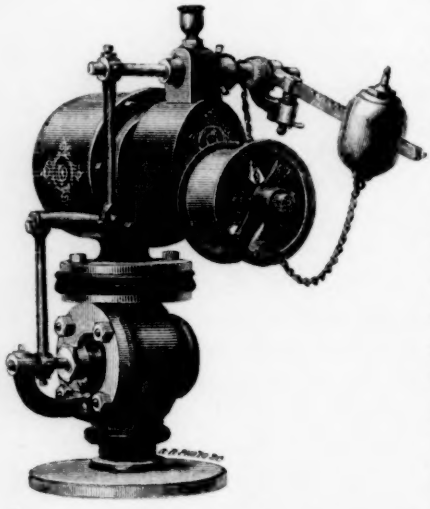
Our readers may remember that in a notice of the Hoosac Tunnel, in Vol. LIV., p. 9, we described, from a letter by Mr. E. S. Ritchie, the machine which has been in use there for several years, which was like this, in material and combination of leyden jar with the machine, but wanted the important feature of compactness and airtight inclosure. Its success, however, is an excellent guarantee for this.

Flow of Water in Rivers.—During the past two years, observations have been made, under the direction of the Superintendent of the Lake Survey, Gen. W. F. Reynolds, upon the flow of water in the several rivers which connect the several lakes, including St.

Lawrence, with a view to settle certain questions upon subaqueous soundings and hidden outlets. The river gauging has, from the start, been entrusted to Assistant Engineer Farrand Henry, who has conducted the work with much care and skill. He devised a "Telegraphic Current Meter," which is said to be more delicate and perfect than anything of the kind heretofore used, and hence the results will be of much value. He has not completed the reduction of all the observations, but the following are approximate results of last year's work:

RIVERS.	Maximum Velocity. Miles per hour.	Mean Velocity. Miles per hour.	Discharge cubic feet per second.
St. Marie	1·30	0·66	90·783
St. Clair	3·09	2·39	233·726
Detroit	2·71	2·04	236,000
Niagara	2·32	1·54	242·494
St. Lawrence	1·00	0·65	319·943

The Huntoon Governor.—At the last meeting of the Franklin Institute, there was exhibited and explained the steam and water-power governor above named.



This instrument consists essentially of a small propeller-wheel, driven by appropriate gearing from the machine to be regulated, and inclosed in a cylinder filled with oil, which is forced to one end by the action of the propeller, and allowed to flow back again by a controllable orifice. If a greater than the normal speed is imparted to the propeller, it will force forward the oil more rapidly than the returning orifice allows for, and thus the propeller will be forced back, notwithstanding the resistance of a weight which is graduated

to keep it up to its position, under the conditions of velocity and resistance. With a less speed, the actions are, of course, reversed.

Among the merits claimed for this improvement, is the ease and quickness with which the apparatus can be adjusted, so as to cause the engine to run faster or slower, by the simple arrangement of weights on the balancing lever.

2d. The perfect independence of its operation as regards the amount of opening to the valve; the velocity alone controlling the motion of this valve, and that equally, whether wide open or nearly shut. This not being the case with the centrifugal governor.

In that instrument, a certain position of the balls means a certain amount of valve opening, and if a sudden demand is made for more power, that is more steam, the balls must fall to obtain a greater opening of valve, but these can only fall when their speed slackens.

That instrument, therefore, cannot, without sensible change of velocity, regulate the admission of large and small quantities of steam.

Special automatic adjustments have been provided to meet this difficulty, but they can only produce their effects after several revolutions, and thus the instrument can never be delicate in its adjustment to meet sudden changes.

In the Huntoon Governor, however, if more steam is suddenly required, the valve may be opened to its fullest extent, in consequence of a loss of velocity in the propeller practically inapplicable, and if the supply of steam thus obtained proves sufficient, and the normal velocity is restored, the regulation goes on, with the valve thus widely opened exactly as before. This instrument thus secures what we might call a practically absolute velocity, in the presence of the greatest irregularity in the power called for, and produced.

We have had an opportunity of examining one of these governors in operation, attached to the engine driving the works of Messrs. William Sellers & Co., 1600 Hamilton Street, of this city. The governor which this instrument displaced was one of the ordinary ball governors; with it the engine ran over speed at high pressures of steam, and under speed at low pressures; in fact, it could not be run with steam much below 60 pounds pressure. This engine has 16 inches diameter of cylinder; 3 feet stroke and makes 50 revolutions per minute, with cut-off and lap of valve at about $\frac{5}{8}$ stroke; but of this we are not sure. Indicator cards showed 42

horse-power; the work required of the engine being very constant and regular. The Huntoon governor was adjusted to run the engine at speed with all the work off; the speed, when doing full work, was found to be the same: the noticeable difference in speed being at low pressure. Thus, at 50 pounds boiler-pressure, the engine runs a little over speed. This is accounted for by the portion of the counter-weight arm decreasing the pressure on the propeller. Cards taken rapidly in succession, show a great variation, indicating all the way from 52 horse-power down to 38 horse-power, the average being as before, 42 horse-power. The sensitiveness of the governor causing it to act as a cut-off. The parties using it seem well pleased with its action; and, indeed, numerous testimonials assure us of its efficiency and value, in all establishments where uniform velocity in the motive power is important.

Editorial Correspondence.

CORNISH PUMPING-ENGINES.

To the Editor of the Journal of the Franklin Institute:

THE remarks of your two correspondents who have been discussing the question of relative merits of the Cornish and Fly-wheel systems of Pumping-engines, do not appear to me to present to your readers the distinctive differences of the two methods of transforming the largely variable power of expansive steam to the impelling of the almost invariable load of a water column, and I send these few observations in hope that the grounds on which these differences are based may be more fully comprehended.

In the Cornish engine we have the application of steam to a heavy mass, which mass is taken from a state of rest, put into accelerating velocity by constant pressure, until the point of cutting off is attained, and is continued in varient velocity during the expansion of the steam until (if the engine is working with its best effect) the mass comes to rest again at the instant of release of the expanding steam. The mass thus acted upon is composed of two unequal parts, placed by some system of leverage so as to act in

opposite directions; the excess of weight which one of these parts has over the other, being the effective motor or load of the engine. The resistance of the air to the changes of velocity of the mass, and the resistance from friction of the machine construction, is comparatively small. The ratio which the excess of weight (of one part over the other, or load) bears to the total weight of the mass, determines the rate of expansion practicable.

In order to start the mass into motion, it is evident that the pressure of steam must have exceeded the (excess of weight of one part of the mass over the other) load; but once started, the motion ceases only (under the conditions stated) when the momentum is expended, and when all additional force, however small, has been absorbed. And the steam will have raised the load to the highest point possible.

This load is now applied to a column of water which, including a resistance due to some small velocity, it balances. The water column commences motion with very gradual acceleration, until at some point the velocity resistance balances the excess of the weight, and the motion then continues through the remainder of the return stroke, at the lowest uniform velocity which the relative conditions of weight to water establish, finally coming to rest upon a cushion of steam which it compresses to form the starting force of the load upwards once more. The utmost effective impulse is thus obtained from the weight. If the boilers are all they should be, (that is, if they will make an average of 12 pounds of evaporation per pound of combustible,) if the steam is carried to 60 or 70 pounds, the stroke be long, the cylinder well jacketed with live steam, the vacuum about 26 inches, the expansion about one-sixteenth to one-eighteenth, and the weight properly proportional to the work, a result of 130 millions will be ensured. That is, 130 millions of pounds of water will be lifted *one* foot high by one pound of coal.

In the Fly-wheel system of Pumping engine, up to and including the fly-wheel, the same efficiency of transformation of force exists as does up to and including the mass in the Cornish engine. No matter how large or how small an impetus is transmitted by the crank, from any variation of expansion or any condition of motion which the crank itself presents, that impetus is imparted to the moving fly-wheel in its fullest value. The friction resistances of the two engines may vary to some small extent, but these are not the real

differences of effect which are worthy of discussion or consideration. Given any Cornish engine lifting its weight, and any rotative one impelling its fly-wheel, and they can be so constructed that the frictions will be identical.

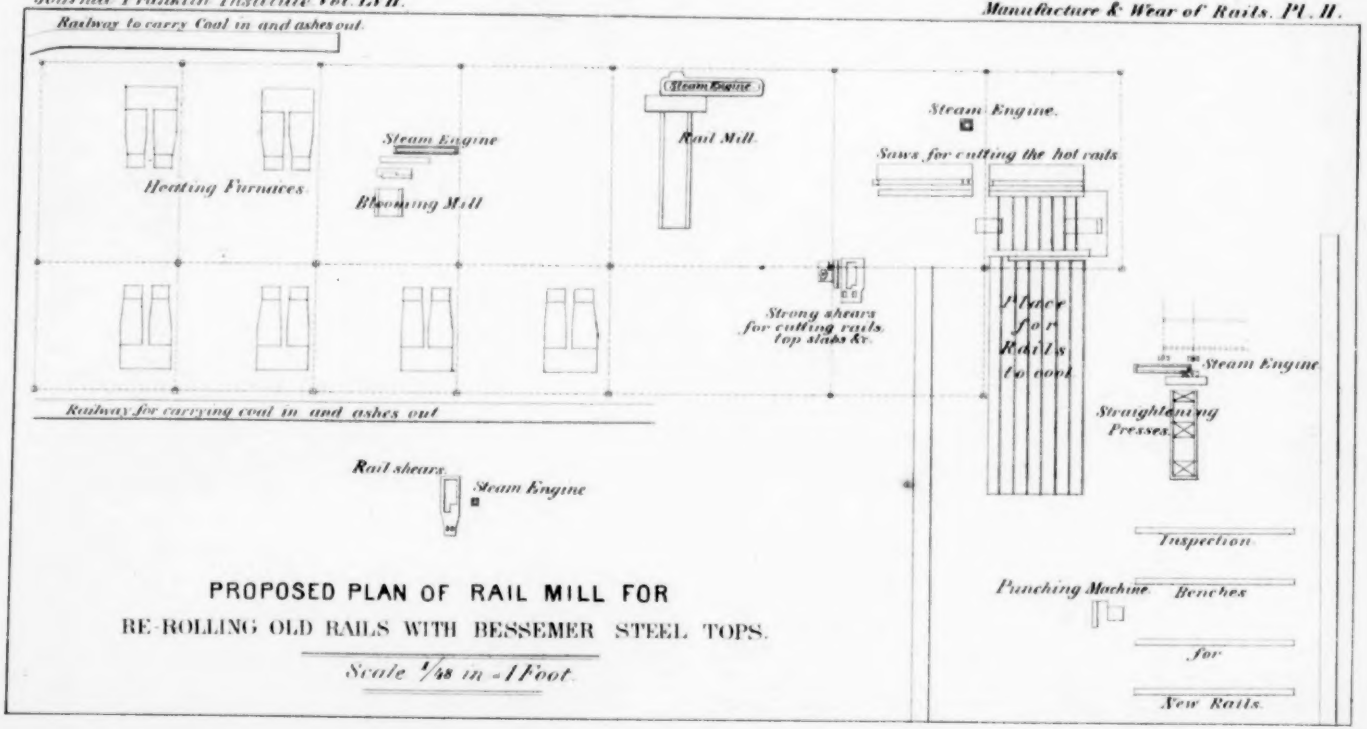
Consequently, there remains only the comparison of the transmission of power from a weight to a column of water with that from a fly-wheel to the same column.

It will be readily recognized that the velocity of the fly-wheel must vary, both with the variable impulses of expansion and with the condition of application through the crank, and also with the resistance of the pumping stroke, but that its effort will be to maintain a constant angular velocity. In fact, the weight of fly-wheel must be such as will insure very small variations of this angular velocity. And in such case it is apparent that the velocity of the pumping plunger must be very nearly that known as the curve of sines, having a maximum velocity, each stroke, nearly $\frac{\pi}{2}$ (about $1\frac{1}{2}$) times that which is imparted by the Cornish engine, and moreover, that the starting and stopping of the water column will be at arbitrary speeds, differing from those which the simple application of an overbalancing weight, or of an elastic counterbalancing force, would have produced.

It is the losses of momentum and the frictional resistances of the water in the pumps, and passages, and pipes encountered in the transformation of a uniform circular motion into an irregular and rectilinear motion, that give the theoretic as well as the practical superiority of the Cornish engine over any possible Fly-wheel one for pumping.

I will only add, that there is yet another engine, based upon reciprocating parts, without a fly-wheel, which has the capacity of rivalling the Cornish engine in its best results, without the requirements of magnitude—almost immensity—which the Cornish engine demands. Yours truly,

ROBERT BRIGGS.



PROPOSED PLAN OF RAIL MILL FOR

RE-ROLLING OLD RAILS WITH BESSEMER STEEL TOPS.

Scale 1/48 in = 1 Foot.

Civil and Mechanical Engineering.

THE MANUFACTURE AND WEAR OF RAILS.

By Christer Peter Sandberg, Assoc. Inst. C. E.

(Concluded from page 394.—Vol. LVI.)

As to the disposal of the rails when worn out, and as to the possibility of re-rolling old rails with advantage by companies far situated from the seat of manufacture, such as the British Colonies, the countries round the Mediterranean and the Baltic, the author thinks that, for railways near the seat of rail manufacture, the best way will be to continue to sell the old rails to the rail mills. For other countries, situated like Sweden, for instance, it becomes important to ascertain whether it would not be more advantageous to re-roll them.

The increasing traffic, the augmented speed, together with the heavier engines now found desirable, have all a tendency to more severe wear, and to render necessary more frequent renewals of the rails. These renewals are executed with more and more difficulty, as the greater number of trains limits the time at disposal, whilst the stoppage of the traffic thus occasioned often results in accidents. These considerations, together with the recurring expenses of renewals, have conduced to the employment of a more durable material for rails, as steel, which is already much used. The new rails have been manufactured either entirely of steel, or iron rails have had steel tops added to them.

In the case of steel top rails, the head has either been entirely formed of steel, or else the upper surface only has been covered with a thinner or thicker top slab, say ½ inch thick on the rail. The top slab has been joined according to the different methods used for forming the pile; so that it has been either laying flat over the wearing part of the rail-head, or it has spanned the mass of iron with its exterior edges, thus fixing the steel without reference to the weld; it has, in fact, been partly mechanically fastened to it. The mode of making the pile at several places, where old rails have been used instead of puddled bars, is shown in the plans, Figs. A, B and C. The pile used at Dowlais, for 120 tons of steel-

headed rails for the Swedish Government Railways, in September last, is shown in plan B, and the one used at Hörde, in Germany, in plan A, all for the manufacture of steel-headed rails.

The use of steel rails has much increased in England, and many railway companies are adopting them as fast as their financial circumstances will allow.

The existence of a cheap raw material, in the shape of old rails, and re-rolling them together with Bessemer steel tops, affords an opening for carrying out the manufacture of rails profitably for railway companies far removed from the seat of manufacture, even when exposed to foreign competition. If such re-rolling were carried out in Sweden, instead of selling the worn-out iron rails in England, the expense of freight to and fro would be saved, which may be reckoned at £2 per ton. The necessary cost of coal would not increase the price of rails more than about 10 per cent. per ton for re-rolling rails in Sweden.

The question is thus reduced to an inquiry, whether the increased cost of manufacture due to the smallness of the quantity to be made, would amount or exceed the remaining part of the difference of the freight, £1. 10. 0. per ton. If so, it would then be of no use to attempt the establishment of a manufacture of rails, either by the government, in connection with other workshops, for the repair and renewal of railway materials of other kinds, such as engines, axles, wheels, &c., or by private capitalists.

An estimate has been made, the particulars of which will be found in the Appendix, of the cost of manufacturing rails in Sweden, composed of Swedish Bessemer steel for the head; No. 2 iron for flange or foot; the remainder of the pile being of old iron rails. The rails are of the Vignoles Section, weighing 66 lbs. per yard.

From these calculations it is shown, 1st. That according to plan A, with the whole head of Bessemer steel, the cost per ton on an annual make of 10,000 tons, is £8. 12. 1.; and 2d. According to plan B, with the top or wearing surface of the rail only of Bessemer steel, the cost per ton, on an annual make of 6,000 tons, is £8. 6. 8.

It therefore follows that the difference between these amounts and £10, the lowest price at which such rails can be imported into Sweden from England, viz: £1. 7. 11. by plan A, and £1. 13. 4. by plan B, respectively represent the nett profit to be derived from the transfer of re-rolling operations to Sweden. In other words, providing this calculation is not too low, this represents, in the first

case, 16 per cent., and, in the second case, about 20 per cent. of the whole cost of production.

In England, the London and North-Western and the Great Western Railway Companies are re-rolling the worn-out rails at their own workshops, where the repairs of other railway materials are also executed; and, at both these places, Bessemer steel has been used for the head of the rails. The other English railway companies are selling their worn-out rails, as there is sufficient competition to prevent them being sold below the market price.

There is no railway company in France which has works for re-rolling the worn-out rails; neither is there any in Belgium, nor in Prussia, the rails being sold to the private rail mills in the respective countries, and being used, in connection with other iron, for rail manufacture.

In Austria, the State railways are carrying on the re-rolling of rails at the States' own workshop at Grätz, while the making of axles and tyres is performed at the States' workshop at Newberg.

In Russia, the rolling of the rails is executed at a workshop near St. Petersburgh, altered for the purpose by a private company. The side irons and top slabs are of English manufacture, but sometimes the top slabs are made at home from scrap-iron. English fuel is used. The Petersburgh and Moscow Railway receive in exchange for their old rails three-quarters of the weight in new rails, and pay a certain sum, according to the specification, for each weight of rails received. By the other great Russian railway, the old rails were at first sent to England; but, for some time, a private iron-work near Petersburgh, called Agareff, has carried on the re-rolling on the following conditions:—The railway company finds one ton of old rails, and receives one ton of new rails, and pays £7. 14. 0. per ton, but has then a guarantee for five years.

Having stated the case of Sweden as an example, other railways in similar circumstances, in the British Colonies, and in the countries round the Mediterranean, may be similarly dealt with. The special conditions being different in each case, make it difficult, if not impossible, to give an example that would suit every case. The principle laid down may be useful, as a guide, as to what is to be done with the rails when worn out.

In the first part of the third division of the paper, as to the best and most economical material to be employed for rails, the particular circumstances affecting Sweden are considered.

From these facts the following conclusions are drawn:—

First. That solid Bessemer steel rails, which are not likely to be manufactured at a cheaper price in Sweden than in England, or £13 per ton, are too dear to use on the Swedish railways.

Secondly. That the Swedish puddled steel rails, which cannot be manufactured for less than £12 per ton, are also too dear for the railways, even if they should last twice as long as iron rails of English make.

Thirdly. That steel top rails, at £10 per ton, are the cheapest for the Swedish railways, being cheaper than rails of Welsh iron at £8 per ton, and that it will thus become the duty of the railways' administration to procure such a steel top rail, not only for the new lines about to be constructed, but also for the maintenance of the existing lines.

In arriving at these conclusions, it must be admitted, that up to the present time, the experience of the durability of the different kinds of rails has not been sufficient to render the conclusions drawn to be thoroughly reliable.

Further: This experience of the durability of the steel top rail, and of the solid steel rail, may not agree with individual cases of failure, where, in consequence of defective welding, the steel head has come off, or where the solid steel rail has broken. At the same time it must be admitted that the process of steel-making, and of welding the steel slab to the rail is, as yet, in its infancy, so that great progress may yet be expected. The principle ought not to be condemned because of individual failures.

Assuming that, under a very heavy traffic, common iron rails 5 years, steel top rails 15 years, and solid steel rails 30 years, and that the iron rails cost £7 per ton, steel top rails £10 per ton, and solid steel rails £15 per ton, and that the old steel top and iron rails are valued at £4 per ton, and the old solid steel at £8 per ton, then with a rail section of 84 lbs. per yard, 250 tons of rails will be required for one mile of double line, and the cost of laying the rails may be estimated at £1 per ton. The following example, as to iron rails lasting 5 years, will serve to explain the way in which the subsequent Annuity Tables have been calculated.

250 tons at £7 per ton	£1750. 0. 0.
Cost of laying down	250. 0. 0.
	£2000. 0. 0.
Which sum, at the end of five years, at 5 per cent. compound interest, becomes	£2552. 0. 0.
The difference between this sum (viz: £2552) and the value of the old rails (250 tons, at £4 per ton, =£1000,) is	1552. 0. 0.
The annuity required to recont. this latter sum in five years, is	£280. 0. 0.

Annuity Table No. 1.

For one English mile of double line, interest being reckoned at 5 per cent., and steel top rails being calculated to last three times, and solid steel rails six times, as long as iron rails.

Where Iron Rails last.	The Annuity would be for		
	Iron Rails.	Steel Top Rails.	Solid Steel Rails.
Years.	£	£	£
2	587	395	**325**
3	417	307	**271**
4	332	247	**245**
5	280	**218**	230
10	179	**163**	205
15	**134**	148	201
20	**130**	140	200

It may be objected that the price quoted for solid steel rails in the foregoing calculations are too high. Rails of this kind have been sold, in some places, as low as £12 per ton; but, for the very best quality, the present price is £15 per ton, and it is only from these last that the experience has been gained as to their enduring six times as long as iron rails. However, Table No. 2 has been calculated for the different kinds and periods, at the following prices, viz: iron rails at £6, steel top rails at £9, and solid steel rails at £12 per ton, crediting the old iron and steel top rails at £3 per ton, and the solid steel rails at £5 per ton.

ANNUITY TABLE No. 2.

Where Iron Rails last.	The Annuity would be for		
	Iron Rails.	Steel Top Rails.	Solid Steel Rails.
Years.	£	£	£
2	574	382	**288**
3	404	283	**233**
4	319	234	**230**
5	268	206	**174**
10	166	**149**	168
15	**133**	136	163
20	**117**	126	150

This Table shows that in all cases, except the last, solid steel rails are the cheapest.

The amount of traffic must, therefore, decide which material it is the most economical to use for the maintenance of the permanent way. For all railways, where ordinary iron rails are worn out in five years, or in a shorter time, solid steel rails are the most economical, at the price quoted in Table No. 1.

Where ordinary iron rails last over five and up to ten years, steel top rails would be the cheapest; iron rails, in these cases, being clearly proved to be the most expensive, although the cheapest where they last from fifteen to twenty years.

As these calculations are founded on the short experience gained up to the present time, in reference to the relative endurance of the different kinds of rails, a still longer trial is desirable.

The foregoing Tables refer to rails of the Vignoles Section Table No. 3 has been made up for the ordinary double-headed rail, according to the prices stated, the consideration being the same as in Table No. 2, except that the chairs have been taken into account. Allowance has been made for 140 tons of new chairs per mile, at £5 per ton, credit being given for the value of the old chairs at £2. 10. 0. per ton. It may be observed, that steel-headed rails are here estimated to last four times, and solid steel rails eight

times, as long as ordinary iron rails—that is, making allowance for the use of both faces.

ANNUITY TABLE NO. 3.

Where Iron Rails last.	The Annuity would be for		
	Iron Rails.	Steel Top Rails.	Solid Steel Rails.
Years.	£	£	£
2	780	379	**296**
3	551	291	**249**
4	436	244	**228**
5	366	233	**217**
10	229	**177**	199
15	183	**166**	.....
20	163	**162**	.....

This Table indicates that the iron rails are in no instance the cheapest; but, on the contrary, that when iron rails last only up to 5 years, solid steel have the advantage, and where the iron rails have a longer duration, then steel-headed rails are the most economical.

It is to be hoped that railway companies having a heavy traffic will give different sorts of rails great attention, and submit them to trials on a large scale; and, on the other hand, that the steel-works will try their utmost to manufacture solid steel, as well as steel-headed rails, of the best sort, for the purpose, so that this important question may soon be decided.

Before concluding, another fact must be taken into consideration, viz: the safety of the three different materials in regard to high speeds, severe climate, &c.

This seems, of late, to have engaged the attention of the railway world, and has been discussed not only in England, but on the Continent. The Swedish Government having undertaken the construction of railways in that country, appointed a committee, composed of many eminent men, to consider it. This committee found it necessary to make experiments with different materials from England as well as Sweden; and, after five years' consideration and study, the report has just been published by Professor Styffe, the

Director of the Government School of Mines at Stockholm. From this report, it appears that the tenacity and elongation of different materials are influenced by the amount of carbon.

The Tenacity Influenced by Carbon.

DESCRIPTION OF MATERIALS.	Carbon. Per Cent.	Elongation. Per Cent.
Swedish Bessemer Steel, Uchartin's Steel,...	1·85 to 1·0	0·3 to 0·9
For Cast Steel.....	0·69 " 0·61	1·2 " 2·1
Bessemer Steel or Iron.....	0·42 " 0·33	1·9 " 4·
	Spec. Grav.	
Iron from lake ores, rich in phosphorus.....	"	0·8 " 3·4
Iron from Dudley, rich in flag & phosphorus.	7·5	2·5 " 4·2
Iron from Middlesboro or Tees.....	7·65	3·4 " 5·9
Puddled Iron, from Sweden and Lon. Man..	7·77 to 7·80	6·1 " 9·5
Swedish Iron, made in refining furnace.....	7·84	7·3 " 7·8

The Absolute Strength Influenced by Carbon.

DESCRIPTION.	Carbon. Per Cent.	Weight in lbs. per square inch when broken.
Swedish Charcoal Puddled Iron.....	0·8	113·381
" " " "	0·7	84·265
" Bessemer Steel	0·8	90·921
" " "	0·55	86·941
" " "	0·50	71·090
" " Iron.....	0·20	48·102
" Puddled "	0·70	83·441
" " "	0·70	83·716
" from another work.....	0·6	73·492
" " "	0·6	82·344
" " "	0·5	78·432
" " "	0·7	86·049

These Tables show that the hardest material has the greatest absolute strength, both before and after permanent set has taken place, but it has the least ductility; on the other hand, a softer material shows the greatest tenacity or elongation; the Bessemer material giving the same result as that prepared from the same pig iron, by puddling, refining, or the cast steel process.

In the diagram illustrating these results, the percentage of carbon and of phosphorus is stated in nearly all cases. The limit for the amount of carbon seems to be for the Bessemer material 1·2 to 1·5 per cent. With a larger amount, the absolute strength, as well as the tenacity, has been found to decrease. When the amount of carbon does not exceed 0·4 per cent., and the material is not worked at too low a heat, the elongation seems to be 16 per cent., or the same as for puddled iron from the same pig iron; and as such Bessemer material is not only much stronger, but also more solid or homogeneous than the puddled material, it deserves a decided preference for all railway purposes.

The few cases of failures of rails by breaking, may be accounted for as the result of too hard a material, not perfectly manufactured, having been made at the earlier period of the introduction of the process. The experience which has now been gained should certainly prevent any recurrence of this.

Iron and steel, when tried for tensile strength under the influence of extreme temperatures, such as boiling water, and at the freezing-point of mercury, has led to the discovery, (contrary to the general belief,) that the tensile and absolute strength is greater during cold than during ordinary temperature—that is, iron or steel is stronger in winter than in summer.

The reason why more breakages occur in winter than in summer is asserted to be due to the external cold affecting the elasticity of the supports (sleepers); and that elasticity in any way given to the rolling stock also favorably affects the resistance of the rails.

However, if the supports have the same elasticity in summer as in winter, as, for instance, would be the case with granite rock, then, Professor Styffe asserts, that the same rails, either of iron or of steel, can resist a heavier blow from a falling ball, at the temperature of extreme cold than on a hot summer's day. Although the experiments have been conducted with the utmost care and skill that science and money can afford, it seems desirable that this theory

should be proved on a larger scale than Professor Styffe has had an opportunity of doing, before it can be relied on.

At a meeting of engineers, at Stockholm, in March, 1867, it was decided that Bessemer steel rails, made from charcoal pig iron, might, without risk, be used 10 per cent. lighter than the English iron rails; and in Austria, this has already been practiced with success by the Engineer-in-Chief, Wöhler.

It must, however, be observed, that the raw material used in both cases, is charcoal pig iron of a superior quality, as compared with that used in England for making Bessemer rails, which may be seen from the following analyses made by two eminent chemists:—

Bessemer Swedish Pig Iron. Fagersta Works. Analyzed by Kohlberg.		English Bessemer Pig Iron. Workington, Cumberland. Analyzed by John Percy.	
	Per Cent.		Per Cent.
Graphite	2·733	Carbon	2·993
Combined Carbon	2·138	Silicon	3·080
Silicon	0·641	Manganese	0·079
Manganese	2·926	Sulphur	0·021
Sulphur	0·015	Phosphorus	0·021
Phosphorus	0·026		

These analyses show that the great difference between the two is the excess of silicon in the English, and of manganese in the Swedish pig iron, thus explaining why the one gives a better result than the other, although worked entirely without the addition of spiegeleisen.

If there be only 0·6 per cent. of carbon in the solid steel, and 0·6 per cent. in the steel head, the safety ought to be the same for all the three kinds, and this would not influence the calculations as to which is the best and most economical material for rails.

Having watched the development of the Bessemer process in England, as well as on the Continent, it seems to the author that, by that process, a good and pure raw material has the same advantage over an inferior one as in all other processes, and that a superior product cannot be obtained from an inferior raw material by that process any more than by others.

In having mentioned Swedish material as an example, it must not be supposed that it is wished to advocate the use of Swedish iron in this country, but simply to draw attention to the better material, as equally good charcoal iron can be supplied from Canada and India, both English Colonies. It may also be remarked that the author's endeavor has been to arrive at the truth, irrespective of prejudice, and that he has no wish to be deemed an advocate for one kind of rail more than any other.

ST. LOUIS AND ILLINOIS BRIDGE.

WE have received, and publish with pleasure, the following letter, a copy of which has been sent also to Mr. Colburn, and will doubtless be published by him in his journal.

ZERAH COLBURN, ESQ.,
Editor "Engineering."

Dear Sir:—In the issue of your valuable *Journal* of September 25th, we find an article on the Mississippi Bridge, at St. Louis, designed by Capt. Jas. B. Eads, which, while favorable to the general plan of construction, discredits the correctness of some of the results of our investigations. We would have replied promptly, had we not preferred to await an expression of Capt. Eads' views on the subject. Capt. Eads has now, in a letter dated at Rouen, Italy, stated his opinions, which in the main, coincide with our own, and has desired us to answer the objections raised by you.

The first and principal objection against the correctness of our results you base on the supposition, that "an arched rib, *per se*, is neither more nor less than a long column."

To support this assumption, you refer to the fact, that in a long column of uniform cross section, subject to two equal and opposite end forces, acting at the centre of gravity of the section, in some cases positive tension is produced by compressive forces, in consequence of variation in the elasticity of the material, though mathematically, the unit strain should be uniform throughout the entire column.

The variations in the elasticity of the material in any cross section are either symmetrically disposed in regard to its centre of gravity, or unsymmetrically. Under the first supposition, they would have no tendency to produce a bending of the column, and

their sole effect would be a distribution of the strain not uniform but proportional to the moduli of elasticity of the elements of the section. In a material of good quality, these moduli cannot vary greatly, and the effect of such symmetrical variations may therefore be neglected in the calculations.

The case is quite different, however, when the modulus of elasticity is smaller on one side of a section than on the opposite side. Then, even if the resultant of forces passes through its centre of gravity, the fibres on the softer (more compressible) side must undergo greater compression, before they offer the same resistance, as the fibres on the harder side, and this causes a deflection of the centre line of the column.

In the succeeding cross sections, the resultant no longer passes through the centre of gravity, and the unit strain must be greater on the softer than on the harder side. The tendency to bend, resulting from the unequal elasticity, is therefore materially increased by the moment of the resultant about the centre of gravity.

It is easily perceived, that from this rapidly increasing tendency to bend, in long, thin columns, considerable deflection may arise, which might finally carry the resultant so far outside the centre of gravity of the section, that the strains produced by the moments of flexure would exceed those due to the direct load, and would produce tension on one side.

The danger in the use of such long, thin columns consequently results from the fact, that a moment of flexure may occur, while *none* can be considered in the calculations.

In the arched ribs of our bridge, the case is quite different.

If you examine our calculations, you will find that moments of flexure are introduced. We consider the rib not as a member subject to direct compression alone, but as a beam subject to the action of direct and transverse forces. The sectional area of the ribs is consequently made much larger than would be necessary to resist the greatest possible direct compression. The latter could be met by an almost uniform cross section of—

$$1{\cdot}8 \times \frac{515^2}{8 \times 51{\cdot}5} \times \frac{1}{12{\cdot}5} = 93 \text{ square inches, when}^{*}$$

$1{\cdot}8$ = load in tons per lineal foot of rib.
515 = span in feet.
$51{\cdot}5$ = rise of the arch in feet.
$12{\cdot}5$ = allowable strains in tons per square inch.

* See Plate I., Diagram 2, of Capt. Eads' Report.

But, without ever considering the effects of temperature, our calculations demand sectional areas, varying for different points from 102 to 180 square inches.

The opposite strains (tensile on one side and compressive on the other), induced by the moment of flexure, and which added to the effects of direct compression, cause an unequal distribution of the strains, are proportional to the distance of the resultant from the centre of gravity of the section. Now it is certain, that the unequal distribution of the load will cause a much greater deviation of the resultant from the centre line of the arch, than any variations in the elasticity of the material could ever produce, especially when, as in our bridge, the rib does not consist of one single piece, but is composed of a great number of smaller pieces, thus admitting of a much greater uniformity of material. The strains arising from variations in the elasticity of the material cannot, therefore, be more than a small fraction of those considered in our calculations.

But, even when considered as a curved column of the proportions of length to breadth = $_{6}^{1}{}_{4}$th, and loaded to the full bearing capacity of its cross section, this rib would be fully strong enough.

It is stated by some of the best authorities on this subject, that solid wrought iron columns, whose ends are fixed in position (as are the arched ribs of the Mississippi Bridge), may be calculated as resisting direct compression only, as long as the proportion of breadth to length does not exceed $_{4}^{1}{}_{8}$ in a column of circular section, and $_{5}^{1}{}_{5}$ in a column of rectangular section. As our ribs are to be constructed of a much stronger and harder material than wrought iron, and as our cross section (in which all the material concentrated at both extremities, resists deflection with its full force), insures much greater stiffness than a rectangular one would produce, it becomes evident that even under this supposition, we kept within the limits of safety. Our margin of safety is considerably increased by assuming the proportions given by you, viz., $_{4}^{1}{}_{5}$. As to the remark, that you are "at a loss to guess what reasons induced us to assume a depth of eight feet in our rib," we would refer to page 4, of Capt. Eads' Report, where you will find, that calculations were made for ribs of various depths, and their results indicated eight feet as the most economical. An increase of the depth of the rib admits of a reduction of the amount of material required to resist an unequal distribution of the load, while at the same time it requires an increase of material to resist the effects of changes

of temperature. The depth of eight feet gave the smallest amount of material to resist these combined factors of strain.

In regard to the stiffness of our bridge, which you seem to doubt, we would most respectfully refer you to page 38 of the Appendix to Capt. Eads' Report, where the vertical deflection of the rib under the most disadvantageous distribution of the load is calculated as not exceeding 2·69 inches, and the greatest horizontal deflection 0·8 inches.

Your objection in regard to the omission of spandril bracing, becomes nugatory if, as we think we have shown, the rib possesses sufficient stiffness in itself.

Very respectfully, your obedient servant,

(Signed), HENRY FLAD,
CHAS. PFEIFER.

THE STREET TUNNEL AT CHICAGO AND ITS MACHINERY.

BY PROF. S. W. ROBINSON, C. E.

AT the time of my visit to the Chicago Washington Street Tunnel, on the 13th inst., the work of tunneling under the river was considerably more than half completed. The approach and arched way on one side are entirely finished as far as to the centre of the river, and work has begun briskly on the opposite bank.

The bed of the river consists of soft, tough clay. It is therefore impracticable, if not impossible, to drive the tunnel without unroofing it, especially under the river's bed. And as it is necessary to continue the work without interrupting the river navigation, and still uncover the roof, it became necessary to establish a coffer-dam that should extend to only about half of the river's breadth at one time. By means of such a dam, the tunnel has been completed up to the centre of the river, and covered again. The dam was then transferred to the opposite shore, shifting at the same time the passage for boats.

The second dam was completed on the 13th inst., and the water partly withdrawn with the pumps still working. Two pumps were in operation; a rotary and a vacuum pump. The latter is of new design, and deserves more particular mention. It will directly be more fully described. The work of uncovering the tunnel bed has begun on this side just beyond the dam, or river bank, and proceeded to a depth of fifty feet, with about the same length and

breadth. When the coffer-dam is emptied, the excavation will be extended into it, and the finished part of the arching brought forward beyond the limits of the river and covered. The dam can then be removed from the river entirely, and the tunnel continued to its second approach.

Two power derricks are in use for hoisting and shifting the excavated material, only a part of which is required to be taken away, viz.: a volume equal to that of the tunnel, the approaches and the masonry. The balance is to be transferred from its native bed to the top of the tunnel. In doing this, the derricks command about a cubic yard at a lift, which is raised at the rate of a foot per second, taking and depositing it about forty-five feet from the centre mast.

The clay is so soft that the sides of the excavation must be supported to protect the foundations of adjacent buildings. This is effected by means of cross timbers pressing against plank walls. The clay is handled with hay forks, it being previously cut into lumps with sharp spades. It was noticeable that the workmen were very careful to entirely free every lump, that it should not be found tied down by the tenacity of a small unsevered fragment. On the whole, the work appeared to be progressing very favorably, with a good prospect of a speedy and successful termination.

The vacuum pump spoken of above, is simple and, it is said, very efficient. It consists of a cylindrical chamber of wood, strongly hooped, being about three and a half feet in diameter, and about five feet in height; having suction and discharge pipes with valves properly arranged, and a steam pipe leading from a boiler; together with a small injector vessel supplied with water. Steam of the desired pressure is forced into the chamber by the steam pipe, when the admission is arrested by a three-way valve, a branch pipe leading therefrom, terminated by a check valve, allows the escape of steam from the chamber until the pressure of the atmosphere is reached. As soon as this occurs, a valve drops in the vessel upon the top of the chamber, introducing a spray jet, by which the remaining stream is condensed, thus forming the vacuum. The valve of the suction pipe is then raised, and water rushes in from below and fills the chamber. This done, steam is again forced into the same chamber in contact with the water, which promptly retires before it through the discharge pipe. The small injector vessel is filled with water from the discharge pipe. When the water

is driven out, the three-way valve checks the steam, and the vacuum is again formed, and the above described operations repeated, which may be so continued indefinitely. The three-way valve was operated by a person stationed for that purpose. The water was raised about twelve feet, to be discharged over the dam. By a similar machine, it is said water has been raised in a jet to a height of over 100 feet.

A question is naturally raised as to whether this is an economical method of using steam. Let us consider this subject briefly. It was ascertained by actual observation with thermometers, that the water discharged over the dam by this pump, was increased in temperature two degrees. By calculation it is determined that the condensation of the steam remaining in the chamber at atmospheric pressure, is sufficient to raise the temperature of the chamber full of water about two-thirds of a degree. There is then imparted one and one-third degrees of heat to the water by reason of the admission of steam to contact with it, and with the wet interior surface of the chamber. The prejudicial result effected by operating this contrivance, is then represented by the mechanical effect equivalent to heating all the water discharged one and one-third degrees. It was determined by Joule and Mayer, independently, that to raise the temperature of one pound of water one degree, requires a mechanical effect equal to raising 772 pounds one foot high. The volume discharged per minute, at the rate of three strokes, is 144·3 cubic feet, or 9018·7 pounds. To raise this twelve feet per minute, requires three and three-tenths horse-power. But to heat it one and one-third degrees, requires per minute, a mechanical effect equal to $9018{\cdot}7 \times 772 \times 1\frac{1}{3} = 9280244{\cdot}$ ft. pounds $= 281$ horse-power, But the steam was all taken from a fifteen or twenty horse boiler. What, then, is the mechanical equivalent in this case?

But let us take another view of the case. To heat a given quantity of water one and one-third degrees, takes twice as much steam as to heat it two-thirds of a degree. Then if 144·3 cubic feet of steam, at atmospheric pressure, will heat the same volume of water, at the ordinary temperature, two-thirds of a degree twice the quantity of steam at atmospheric pressure will raise the temperature of 144·3 cubic feet of water one and one-third degrees. If the last named quantity of steam, which is the amount lost by incidental condensation, be used each minute in a steam cylinder at sixty pounds apparent pressure, it would perform the work of two and

a half horses. Taking this as the prejudicial work of the vacuum pump, and 3·3 horse-power, which was shown above to be the theoretical work required to raise the water, we find that the work lost is 0·76 of the useful effect; and 0·43 of the total effect; which is a large per centage for even ordinary pumps. If this is true, it appears from the results of the experiments cited, that as a device for raising water, the vacuum pump is not an economical machine, except where convenience demands its use, or where its temporary employment justifies the application in preference to more costly machinery.

One of the most essential pre-requisites for economical results with this device, is, that the surfaces with which the steam and water have alternate contact, must be non-conductors of heat. Indeed, the measure of success depends upon the degree to which this principle attains. One might at first naturally suppose that the cold water surface would contribute to rapid condensation of steam. But it is very well known in the science of physics, that water is one of the poorest conductors of heat; which becomes particularly apparent in the downward direction where conviction fails to act. A remarkable statement, substantiating this fact, on a large scale, appeared in the *Scientific American*, early last spring, in which it was confidently asserted that one of two boilers of moderate size, established in separate arches, connected by a steam pipe having no separating valve, had frequently been fired while the other was not, although still containing the ordinary supply of water; and that the water in the unfired boiler had not changed materially in temperature after a considerable interval of time. From this, together with the facts relating to the vacuum pump, it appears that water is a poorer conductor of heat than the wet wood of the interior of the chamber, as the amount of condensation incident upon the ejection of water is very considerable. If so poor a conductor as wood is barely suitable for the interior of the chamber, iron could not possibly answer, notwithstanding the want of its strength to guard against explosion; although iron cylinders lined with wood or other non-conducting material, might serve the purpose well, some good non-conducting material having little inclination to retain water, as wet would form the best lining. That so good a conductor as iron cannot form the interior surface, is strikingly shown by the performance of certain surface condensers. In Hamilton, Ontario, at the machine works of the Northey Brothers, a twelve

horse engine exhausts into a cylindrical wrought iron chamber about two and a half feet in diameter, and thirty feet high. It is of boiler plate, about five-sixteenths of an inch thick. A stream of water delivered upon the top flows down over the whole exterior surface. This chamber maintains nearly a perfect vacuum.

S. W. ROBINSON.

University of Michigan.

THE ECONOMICAL CONSTRUCTION OF BEAM TRUSSES.

By G. S. MORISON, C. E.

(Concluded from page 399.—Vol. LVI.)

Case of Four Continuous Spans.

THE two central spans are supposed equal, and each one-quarter larger than the end spans, and as such a bridge is perfectly symmetrical, only the first two spans need be examined. The truss is supposed to be a Warren girder, single system, arranged for a through bridge, the floor being supported on the bottom chord at he end of each panel, and hung by a vertical tie from the upper chord at the panel centres. The depth of truss is taken at thirty feet, and the length of panel the same; the number of panels in the end spans sixteen, and in the central spans twenty, making the length of these spans respectively, 240 and 300 feet. The dead load is assumed to be 1,000 pounds per foot, and the moving load 1,500; making for the bridge of two trusses a total load of 5,000 pounds per foot. This form of truss is selected on account of its simplicity, an equal amount of weight being thrown upon the truss at the intersection of each brace with either chord.

Representing the chord strains at the five points of support by $s_1\ s_2\ s_3\ s_4$ and s_5, the lengths of the four spans by $l_1\ l_2\ l_3$ and l_4, and their respective loads per foot by $w_1\ w_2\ w_3$ and w_4, we have—

$$l_2 = l_3 = 1{\cdot}25 l_1 = 1{\cdot}25 l_4 = 1{\cdot}25 l,\ s_1 = o\ s_5 = o$$

and equation (6) gives—

$$18\ s_2 + 5\ s_3 + \frac{l^2}{h} w_1 + 1{\cdot}953125 \frac{l^2}{h} w_2 = o$$

$$5\ s_2 + 20\ s_3 + 5 s_4 + 1{\cdot}953125 \frac{l^2}{h} w_2 + 1{\cdot}953125 \frac{l^2}{h} w_3 = o$$

$$5\ s_3 + 18\ s_4 + 1{\cdot}953125 \frac{l_2}{h} w_3 + \frac{l^2}{h} w_4 = o$$

solving these three equations—

$$s_2 = \frac{l^2}{h}\left(-\cdot06004w_1 - \cdot085755w_2 + \cdot022751w_3 - \cdot00448w_4\right)$$

$$s_3 = \frac{l^2}{h}\left(\cdot01613w_1 - \cdot081905w_2 - \cdot081905w_3 + \cdot01613w_4\right)$$

With reference to the first span, two cases only need be considered; when s_2 is most intense, first, second, and fourth spans loaded (▪▬▬▪▬▬▪▬▬▪) and when the strain at the centre is greatest first and third spans loaded (▪▬▪▬▬▬▪▬▪▬▬). With reference to the second span, three cases must be examined, when s_2 is most intense)▪▬▬▪▬▬▪▬▬▪), when s_3 is most intense, second and third spans loaded (▬▬▪▬▬▪▬▬) and when the strain at the centre of the span is greatest, second and fourth spans loaded (▬▬▪▬▬▪▬▬▪). These cases with their complements form three groups, two of which will be applied to the first span, as follows —

Spans 1 and 2. $w_1 = w_2 = w_4 \quad w_3 = w_0$

Spans 1 and 2. $w_1 = w_3 \quad w_2 = w_4 = w_0$

Span 2. $w_1 = w_4 \quad w_2 = w_3 = w_0$

For these three groups, the equations expressing s_2 and s_3 become

$w_1 = w_2 = w_4$ $\quad s_2 = \frac{l^2}{h}(-\cdot15928w_1 + \cdot02275w_0)$ $\quad s_3 = \frac{l^2}{h}(-\cdot04965w_1 - \cdot08191w_0)$

$w_1 = w_3$ $\quad s_2 = \frac{l^2}{h}(-\cdot03729w_1 - \cdot09624w_0)$ $\quad s_3 = \frac{l^2}{h}(-\cdot06578w_1 - \cdot06578w_0)$

$w_1 = w_4$ $\quad s_2 = \frac{l^2}{h}(-\cdot06452w_1 - \cdot06300w_0)$ $\quad s_3 = \frac{l^2}{h}(+\cdot03226w_1 - \cdot16381w_0)$

The symbol w_0 is used to denote the weight per foot of those spans differently loaded from the first span.

Substituting the numerical values of l, h, w_2 and w_0, we have for each of the six cases under consideration—

▪▬▬▪▬▬▪▬▬▪	$s_2 = -677650$ lbs.	$s_3 = -395570$ lbs.
▪▬▬▪▬▬▬▬▬▬	$s_2 = -179330$ "	$s_3 = -488490$ "
▪▬▬▪▬▬▪▬▬▬▬	$s_2 = -352240$ "	$s_3 = -442030$ "
▬▬▬▬▪▬▬▪▬▬▪	$s_2 = -504740$ "	$s_3 = -442030$ "
▪▬▬▪▬▬▬▬▪▬▬	$s_2 = -430690$ "	$s_3 = -159690$ "
▬▬▬▬▪▬▬▪▬▬▬	$s_2 = -426290$ "	$s_3 = -724370$ "

It will be seen that the sum of the values of s_2 or of s_3 for any

pair of complementary cases is a constant; the same is true of the chord strains at any point in the bridge.

Having determined the strains over the points of support, it remains to draw the general curves of strain. These are given on Plate 4. The parabolas corresponding to each pair of complementary cases are drawn in similar dotted lines, thus showing at once their connection, and making evident their complementary character; the curves denoting the strains in unloaded spans are easily distinguished by their flatness. The heavy line, A D E F C H I K L, shows the maximum strain at every point without regard to size (B F being equal to B M and C L to C N), except between D and E, G and H, and I and K, where a generous allowance is made for irregularities at and near the points of reversal, this allowance being such as to make the section of the proportioned chord between these points about one-half the maximum section. For the sake of comparison, the curves of strain in the same spans when isolated are given also; these curves are the parabolas A O B and B Q C, the maximum strain in the first span being 600,000 pounds, and in the second, 937,500 pounds. The figures on the truss below are taken by measurement from the diagram, and express in units of 10,000 pounds the chord strains in each panel. The curves for the unloaded spans all fall within the limiting line, though about the points of reversal they indicate that the maximum strain occurs when the span is unloaded. Case third, shows that at times the chord strains may be negative through the whole length of an intermediate span. This might occur even in an end span, if the end spans were very much shorter than the intermediate, but as the effect would be to lift the end of the bridge from its abutment, so great an inequality should be carefully avoided.

The average maximum chord strain in the first span (including the surplus about the points of contrary flexure), is 348,750 pounds, and in the second span, 403,500 pounds. In an isolated 240 feet span of the same depth, and carrying its same weight, it would have been 400,000 pounds, and in a similar 300 feet span, 625,000; the reduction due to continuity being about 13 per cent. in the former span, and over 35 per cent. in the latter span, and over 27 per cent. in the whole bridge; and this reduction is on the supposition that the dead loads are equal in each case, whereas they would really be much greater in the isolated spans.

In the first span, the shearing strain will always be less at A and

greater at B than if the span were isolated; a change which continues through the span, and throws the mean vanishing point back towards A. The greatest strain at A occurs in case 3, and is equal to—

$$\frac{(w + w^1)\, l}{2} + \frac{s_2\, h}{l} = 255970 \text{ pounds.}$$

and the most intense strain at B, in case 1, it being—

$$-\frac{(w + w^1)\, l}{2} - \frac{s_2 h}{l} = -384{,}706 \text{ pounds.}$$

In the second span the maximum strain at B occurs in case 1, being the 403,208 pounds, and the maximum at C, in case 6, when it is 404,808 pounds. Hence it appears that in the first span for a part of its length, the web may be made lighter than in an isolated span, but for the greater part of this span it would be heavier, while through the whole length of the second span it would be a little heavier than in a disconnected span; the counterbraces, if the web does not counterbrace itself, must also be carried farther on each side of the centre. The increase will not exceed 14 per cent. of the weight of an isolated web in the end span, nor 16 per cent. in the intermediate, an increase which, as the weight of the web is always much less than that of the chords,* may be disregarded by the side of the great saving effected in the chords.

In spite of the great economy of continuous spans, their adoption has not met with universal approval. The occasional failure of bridges built in this way, has caused an unfortunate prejudice against them, but these failures have occurred in bridges in which the spans, though made continuous, were built on the same principles as if isolated, for the most part in wooden structures, and are to be attributed solely to the ignorance of the engineers who built such structures. The failure has usually been in the top chord, which being packed only to resist compression, has been torn apart over the piers where it is heavily strained in tension. On having the upper chords cut, these bridges have done well, as they are then subjected to strains only of that character which they are adapted to bear. Such failures, occurring exactly where theory would have predicted them, rather prove the correctness of the reasoning by which continuous spans are proved to be economical, than furnish any argument against their use.

* Theoretically, the weight of the web in an isolated span, does not become equal to that of the chords, until the depth of truss is made about one-third the length.

In an isolated span the top chord is strained through its whole length in compression, and the bottom chord in tension; each chord may be constructed of that form and material best adapted to its particular strain, and effective connections will be made by cheap and simple details. In a continuous girder, on the contrary, this unity of action is lost, and each chord is liable to be strained for a considerable part of its length, alternately in tension and compression. In structures entirely of wood, this would be a source of little difficulty, as a wooded chord properly packed to resist tension, acts equally well in compression; in composite structures, where wood is only used to resist compression, continuous spans become impracticable; while in structures entirely of iron, cast iron must be excluded, and both chords constructed of wrought iron alone. The experience of engineers, however, has not been favorable to the use of cast iron, even in isolated spans, and it is not unlikely that the general adoption of a form of bridge, which would compel its abandonment, would be an advance in the direction of safety. If the details of a chord, intended to act only in one way, are much cheaper than those of a chord adapted to both kinds of strain, this is a matter of practice rather than of necessity, and there is no good reason why a simple detail may not be contrived, which shall prove an effective connection both against tension and compression. The straining of the same iron in opposite ways, has been supposed to act injuriously, but recent experiments indicate that it is otherwise, as might be expected, from the fact that opposite strains tend to retard the permanent set, which is sure to weaken eventually any material subjected continually to the same kind of a strain.

The calculation of strain in a continuous girder is longer and more difficult than in an isolated span, and the results obtained are not so strictly accurate. The strains over the piers of a continued truss are deduced from the curvature of that truss when strained by the action of a load, this curvature being assumed to be everywhere proportional to the chord strains, an assumption which is strictly true, if the chords are everywhere of uniform section, but which leads to a slight error when their section is made variable. This error is at most very slight, and of a kind easily guarded against. The effect of increasing the sections of the chords at the ends of the spans, where the strain is most intense, is to flatten the curvature at the ends, thus throwing the points of reversal towards the centre

of the span, and consequently increasing the strains over the piers, and diminishing that at the centre of the span. This variation will be effectively counteracted, but putting a slight excess of material in the chords of the end panels, but it is so slight that the best European engineers have considered that it may be safely neglected. In the multitude of uncertainties about the action of a moving load, even in isolated spans, the peculiar effects of which are the result not only of its character as a variable partial load, but are also due to action of motion itself, the vibrations caused by the rapid succession of shocks, and many other irregularities which can be guarded against only by the adoption of a large factor of safety, any slight variation like that alluded to above, especially if its general character be understood, may readily be set aside. Still, though the results we now have may be abundantly accurate for practice, there would be no small satisfaction in having them made strictly correct, and, in the language of an eminent French engineer, though "trusses constructed in this way act favorably, and resist well all the tests to which they are subjected, a fact now proved by numerous examples * * * there is no doubt that if we could succeed in so altering the principles of the method as to render it more rigorous without making the use of it much too long and difficult, constructors would be glad to accept such a change which would mark a real advance in science."*

First among the merits of continuous spans, is their great economy, which can hardly be overrated, as continuity reduces the weight of an intermediate span nearly one-third, and makes it possible to contract spans of three hundred feet, at a cost per foot but little in excess of that of a two hundred foot span, thus saving the cost of a foundation in six hundred feet; but there are other advantages of too great weight to be entirely overlooked. In an isolated span, the truss is heaviest at the centre, where weight acts at the greatest disadvantage, but in a continuous girder, the weight of material both in chords and web is near the piers, where it imparts but little strain to the truss. When the spans of a bridge are disconnected, the weight of each span must rest on or near the edge of the piers, and the action of a heavy passing load will be to throw the additional weight first upon one side of the pier, and then on the other; in a continuous girder, the bridge seat may be placed directly over the centre line of the pier, so that any additional weight will be thrown on

* Bresse. Avant Propos. Partie IIIme. Mecanique Applique.

the axis of the pier, and the tendency to rock reduced to a minimum. The deflection of a span is less if it is connected with the adjoining spans than if standing alone; this diminution being due both to the decrease of strains and to the reversals of curvature, the same amount of curvature causing a greater deflection if the curve be always in one direction, than if it be broken and reversed.

As regards facility of erection, the advantage usually lies with disconnected spans; but in positions where it would have been difficult to erect suitable false works, or when it has been considered desirable to have the construction of the superstructure go on simultaneously with the building of the piers, foreign engineers have often built continuous trusses on the land at the end of the bridge-line, and on the completion of the masonry, moved the whole structure forward into position, a process which would have been impossible with disconnected spans. In a bridge with riveted chords, it is no small advantage to be able to put the whole together on the land where the riveters will have abundant room for their forges and good standing room; but if it be considered preferable to erect the structure in place, there is no inherent reason why the parts of a continuous truss should not be as completely finished in the shop and as rapidly put together in place, as those of an isolated span.

BELTING FACTS AND FIGURES NO. II.

By J. H. Cooper.

(Continued from page 388.—Vol. LVI.)

Joining the Ends of Belts.

"Shoe-pegs are successfully used here for joining belts to stand the effects of water and oil."—T. G., Providence, R. I., in *Sci. Amer.*, January, 1854, p. 147.

"After many plans of waxed-ends, laces, rivets and bolts, with and without plates, have been tried in joining belts, the best plan, in my opinion, for a permanent joint, is to scarf the ends as usual, then glue and bind the ends together with hand-screws, until the glue is set, then apply as many shoemaker's pegs as are necessary, dipping each into glue before driving it in. The pegs are then pared smooth on both sides, and the joint made of equal thickness with the rest of the belt.

"If not exposed to water, I will warrant this joint to last as long

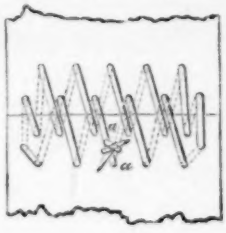
as any other part of the belt."—Machinist, in *Sci. Amer.*, March, 1854, p. 217.

"If pegs are used, they should be inserted on the side next the pulley."

The usual way of joining the ends of a belt—that is, by means of the leather thong—is the best after all, because it is the most convenient; the thong being an article more readily obtained and applied than any other of the numerous and ingenious means devised for securing the ends of a belt.

In the use of thongs, it is the practice of some engineers to cross them in lacing on both sides of a belt; with others, to cross them on the outside only, laying the double strands evenly on each other in the line of motion and on the pulley side of the belt, which experience proves to be the better way.

We present, below, a plan, altered from the original, in which the two ends, *a a*, of the thong are tied in the middle of the belt.



"I have had experience for upwards of twenty years in such matters, and do not cross the lacing at all. I make two rows of holes, as shown in the engraving.

"By this plan, I find a lace will last twice as long as it will when crossed."—W. A., in *Sci. Amer.*, January, 1866, p. 52.

To measure the length of a belt in coil, use the following formula.

$$L = (D + d)\, n \cdot 1309$$

In which L = length of belt in feet.
D = mean diameter of roll in inches.
d = " " eye " "
n = number of turns.

W. S. A., in *Sci. Amer.*, December, 1866, p. 423.

Effect of disproportion of connected machinery.

Sometimes a belt works badly from causes outside of its own motion and proportions.

We have a case in practice which will forcibly illustrate this. A 46-inch pulley, on the "line" shaft, drives a 5-foot pulley on a 4-inch shaft, at the rate of 73 revolutions per minute, by a 12-inch open belt. This shaft is 7 feet 8 inches below, and 2 feet aside of the "line" shaft, and carries an 8-foot fly-wheel of 3,750 lbs. weight on its middle, and a crank with a double pin on its overhanging end, which latter is connected with and drives two marble saw-frames,

one very heavy, the other of medium size. The belt runs slack and free, and has not been touched at the lacings during six months of very steady and satisfactory running.

Before the 8-foot fly-wheel was put on, a 6-foot fly-wheel, of about 1,450 lbs. was used, which a long, troublesome experience proved altogether inefficient. The belt had to be run very tightly; it tore frequently at the lacings—even when the laced ends were doubled to make the stronger joining—and at all times while running, the lack of momentum of the wheel caused unsteadiness of motion in the whole system of gearing in the mill.

Driving Power of Belts.

"As regards the width of the belt, this will be found ample with respect to friction, if we calculate the cross-section of the same for the strain to be transmitted, in which case one-eighth of an inch square is allowed for every 5 lbs. strain."—C. D. Abel, in *Weale's Series.*

"The working strain of a 9-inch belt, on 4 feet pulleys, under the effects of a tightener, in use nearly three seasons, at a velocity of 1,571 feet per minute, without ever failing, was found to be 28·3 lbs. per inch of width. Experiments proved that an increase of 25 per cent. of the above load endangered the splicings and safety of the belt."—J. A R., in *Sci. Amer.*, July, 1865, p. 68.

"Morin concludes that we may, without any risk, and with the certainty that they will run a long time, make them support tensions of 355 lbs. per square inch of section."—*Frank. Inst. Jour.*, July, 1844, p. 27.

"Good belting of, say, $\frac{3}{16}$ inch thick, should sustain a tensional strain of 50 lbs. per inch of width, and without serious wear, for a long time."—*Appleton's Mech. Mag.*

Haswell, in his Engineer's Pocket-Book for 1867, says: "A leather belt will safely and continuously resist a strain of 350 lbs. per square inch of section."

We are indebted to Mr. R. H. Thurston, U. S. N., for the following:—

$$W = \frac{7000 \times H P}{s v}$$

In which W = width of belt in inches.
H P = indicated horse-power transmitted.
s = portion of circumference of smaller pulley covered by belt, in feet.
v = velocity of belt, in feet, per minute.

Mr. Thurston considers 100 lbs. per inch of width on ordinary

belting of, say, $\frac{3}{16}$ inch thick, a fair working load. Then calling t = tension, and inserting same in the formula above, we have:—

$$w = \frac{700{,}000 \text{ H P}}{s \text{ v } t}$$

From a treatise on machine belting, published by Hoyt Brothers, of New York, we extract the following:—

"The Table inserted below, gives the relative driving power of Leather Belting, with both grain and flesh side to pulley; also, of Rubber, Gutta Percha and Canvass. The pulleys on which the experiments were made were the same in size, on one shaft, and their surfaces severally of leather, polished iron, rough turned iron, and of polished mahogany. The bands were passed over the pulley, one end made fast and stationary, and, on the other, one pound weight was suspended to every square inch contact surface of the band and pulley.

"The number of pounds required to slip the band are given; also, number of pounds strain on the band at which it will cease to slip; and also, number of pounds required to make it continue to slide.

"The belts were in like condition, and had the same contact surface, the same strain, consequently it is easy to determine the relative value of each, for driving machinery, also that of the pulleys.

TABLE B.

	Leather, Grain side to Pulley.			Leather, Flesh side to Pulley.			Rubber.			Gutta Percha.			Canvass.			Relative value of different pulleys.
	Commence to slip.	Cease to slip.	Slide.	Commence to slip.	Cease to slip.	Slide.	Commence to slip.	Cease to slip.	Slide.	Commence to slip.	Cease to slip.	Slide.	Commence to slip.	Cease to slip.	Slide.	
Pulley with Leather surface	6	2½	10	3½	2¼	7	2½	1½	5	2½	1¼	3½	1¾	1	1¾	52
Polished Iron surface	1½	1	9	1¼	¾	6½	1¼	¾	4½	¾	½	2½	1	½	2	33¾
Rough Iron surface	1½	¾	3	1½	¾	2¼	1¼	¾	4	¾	½	1½	1	¾	1¼	21½
Smooth turned Mahogany	3¾	2¼	4	3	1½	3¼	2¼	1½	4½	2½	1	2½	1¾	1¼	13	36¾
Relative value of each belt	45¼			33½			29¾			19¾			15¾			

(To be continued.)

Mechanics, Physics, and Chemistry.

ON ELECTRICITY APPLIED TO REGISTERING VIBRATIONS.

THE laws which govern the vibration of cords or wires, have been obtained by comparing the sounds they produce, with the notes of a syren. Without questioning the accuracy of this method, it will still be desirable to obtain the laws of vibration without regard to the effects which vibrations produce; a *direct registry* cannot fail to be more satisfactory.

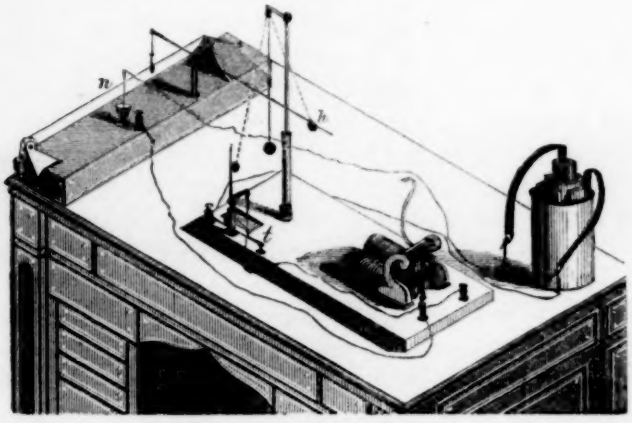
Now it is clear that however rapid may be the vibrations of a cord, the velocity of the electric force is greater; moreover, it is not impossible to make a succession of electric impulses produce a corresponding succession of *permanent* effects, which can be seen and counted, so that if a vibrating body can be made to open and close an electric circuit, the electric force may be depended on to register its vibrations.

The practical questions are, 1st, How shall a vibrating body be made to open and close an electric circuit without having its motion embarrassed? 2d, How, in a legible manner, can the number of these rapid impulses be registered? And 3d, By what means can the time of vibration be accurately measured?

To register the vibration of cords and piano wires, the following arrangement of apparatus has been made. Through the middle point of the vibrating cord, passes a firm cambric needle, *n*, the point of which, will, when the cord is at rest, be very near, but not in contact with the surface of mercury contained in a cup beneath. A galvanic battery is connected, one pole with this cup, the other with a trough, *t*, containing mercury, into which dips the end of a wire bent twice at right angles, and turning freely upon a hinge. To this wire is joined one end of the helix of an electro-magnet, while to the other end of the coil is attached a flexible metallic thread (a ravelling of gilt lace), tied into the eye of the needle, which passes through the vibrating cord. Now, by the vibration of the cord, the needle point will be brought in contact with the surface of the mercury under it at the end of every double vibration, and a current of electricity darts through the wires, magnetizes the electro-magnet, which pulls the armature to its poles, and brings the registering point in contact with the paper. As the

paper is drawn swiftly along by clock work, while the armature with its sharp and soft lead pencil point is in motion, the vibrations of the cord are registered upon the paper in a line of distinct black dots, easily counted.

To measure time, in the present form of the apparatus, a pendulum is used. The pendulum when drawn to one end of its arc, rests against one arm of a lever, *h*, while the other arm carries a pair of pluckers which grasps the cord. A pressure of the finger causes



this finger to release, at the same instant, the pendulum from one end, and the cord from the other. The wire, whose lower end dips into the trough of mercury, can at any time be brought into the arc of the pendulum, by moving the block to which it is fastened, without breaking the circuit, but when this is done, the ball will strike its upper end, and knocking it over, lift the lower end from the mercury, and open the circuit. The motion of the armature begins with the beginning of the first vibration of the pendulum, and stops at the end of one, three or any odd number of seconds, and the number of dots left upon the paper, shows the number of vibrations of the cord.

This apparatus applied directly to the wires of a piano in daily use, gave the following results:

Notes.....	C	C♯	D	D♯	E	F	F♯	G
Vibs. per sec.....	127·5,	117·5,	114·5,	107·8,	101·5,	981,	92·8,	87♯,

G♯	A	A♯	B	C
8♯·8,	76·♯,	74·♯,	67·♯,	64·2.

Each of these numbers is the mean of a set of experiments, but

in no instance did the numbers in the same set differ by more than a single dot, which must correspond to an error of *less than one-half of one vibration.*

In this set of experiments, however, the adjustments of the apparatus were not such as extreme accuracy would require: in those by which to verify the *laws of vibration* great care was taken that they should be. The two points to be accurately gained are 1st, to adjust the lever, *h*, so that it will release the pendulum and the cord at the *same instant*, and 2d, to adjust the bent wire so that it will break the circuit at the end of the arc of the pendulum.

The first adjustment seemed to be accurately made, as follows: a *steel* wire was fastened firmly at its middle point with one end resting upon the short arm of the lever, and the other bent under the end of the long arm. The ends of this elastic wire must then follow the motions of the lever. By trial, the exact positions of these ends at the time when the ball and cord were released were found, and *at these points* were placed the *ends* of two small wires, which came from the two poles of the battery. A circuit was thus arranged with two breaks, which were to be closed by the motion of the lever. If both are closed at once, then a galvanometer in the circuit will announce the passage of electricity; but unless they are, there will be no motion of the needle. When, therefore, by a sudden pressure on the lever, the needle moves, there can be little doubt that the cord and the pendulum begin their vibrations at the same instant.

The same method secured the second adjustment also. The upper end of the bent wire passed the end of one battery wire at the moment when the pendulum reached the end of its arc. A projecting point, cemented to the lower bend of the wire, passed the other battery wire at the moment when the lower end left the mercury in the trough. If, then, the needle of the galvanometer moves, we know that the two openings in the circuit are closed at the same instant. Still farther, the bent wire is small, and so nearly balanced on its hinge that a single grain weight was force enough to throw it over, while the pendulum ball was of lead, weighing about ten ounces; the wire could not impede the motion of the pendulum.

The apparatus for these adjustments is not a permanent part of the instrument, but it can easily be made so, and then *every experiment would be tested* by the motion of the needle. Only the first adjustment would need this.

It is not to be supposed that this form of the apparatus is the

most efficient that can be devised; experiments indicate, for example, that a *chemical* registry may be used to advantage. Moreover, it seems clear that by this method the vibrations of not only wires and rods, but of other bodies, whose amplitude of vibration is at all appreciable, may be registered. And when we remember how large a place the theory of vibrations holds in modern science, may not the importance of the subject lead other experimenters of greater skill and more abundant resources, to welcome the hints here offered.

THE BEST MODES OF TESTING THE POWER AND ECONOMY OF THE STEAM ENGINE.

By Charles E. Emery.

Late of the U. S. Navy and U. S. Steam Expansion Experiments.

It is unnecessary for us to do more than simply call attention to the extended usefulness of the steam engine. It is the only motor that has successfully competed with or supplanted the changeable and uncertain power derived from animal muscle, and the natural forces of wind and water, and its varied adaptations and applications have brought it into general use throughout the civilized world, not only in stupendous water works and manufactories, and in furnishing reliable and rapid communication by land and sea, but also in reducing the physical exertions of both sexes in the less grand but more important operations of the producing community in the forest, field, and farm house.

Surely, then, the steam engine is not an experiment. Years ago, it was made a success, and soon became a necessity; and notwithstanding the grand discoveries that have been made in theoretical and practical science, the steam engine has to this day remained unchanged in every important particular. The principal advance has been in the perfection and general adoption of the simple high pressure engine. Many of the so-called improvements were mere variations in form and in the details of construction, which often failed to produce as economical results as older well tried mechanism. Nearly all the true improvements have been in workmanship and in adaptations, and applications to various uses. A few of the general principles which influence the economy of the steam engine have long been known, and our manufacturers have in very many cases claimed a superiority for their engines on account of alleged

excellence in the details of the valve gear, or other mechanism, designed to secure the results promised by theory, forgetting that theoretical propositions are of little value, unless all the conditions assumed are the same as those in practice, which is rarely the case. It therefore often happens that engines, which in the opinion of the educated engineer, possess many of the elements considered necessary for economical workings, do not have those elegant, moving details, which fix the attention of the amateur, and delight the eye of the skillful mechanic. Business men seek only to sell, and therefore push into chief importance such points as the purchaser can see and understand.

Statements are made also regarding actual performance, but they cannot be considered impartial, because the trials upon which they are founded are made by interested parties, with no competition present. We have therefore to conclude that the purchaser of a steam engine has to base his selection almost exclusively upon the excellence of simple, mechanical details, and having done this, if the engine works well, and especially if it does better than the old neglected one, with its worn out boilers, he is entirely self-satisfied, and ready to sign a recommendation to the public of the engine which he has selected, thereby benefitting the manufacturer, and flattering his own vanity. But little true progress can be made in this way, as each manufacturer and purchaser knows little more than the result of his own experience.

To bring the steam engine to a high standard of efficiency, accurate, comparative trials should be publicly made of every different system of construction. This would be most satisfactory, if it could be done in the same place, doing the same work, under the same circumstances. This would require the erection of costly experimental fixtures, which could be done by private enterprise for expected gains, or by the combination of several wealthy manufacturers, or, better, still, by some scientific organization. The majority of cases must, however, be reached by trying the steam machinery in the actual performance of the duty for which it has been purchased. We desire, then, in our present inquiry, to ascertain methods and means to test the power and economy of the steam engine in a strictly scientific manner, which shall be above criticism, and *also* under the practical circumstances of every-day use.

We propose first to mention some of the *terms* in general use on the subject, then to discuss the ways and means employed to measure

the power and its cost, and afterwards to select proper units of comparison and point out the manner of their practical application.

A steam engine is simply a *heat* engine. The *heat* evolved by the combustion of fuel is imparted in the boiler to *water*, separating and agitating its molecules, and thus forming *steam*. The steam exerts *pressure*, varied according to its density, upon all sides of the vessels in which it is enclosed. This pressure or *force* is measured in *pounds* per square inch. The elastic force of the steam acting upon the engine piston, produces *motion*, which is measured in feet. The combined effects of *force acting through distance* produce mechanical *work*, which is measured in *foot-pounds*. The number of foot-pounds which an engine is capable of developing in a given *time*, expresses the power of the engine. The unit of the power is one *horse-power*, the value of which is conventionally fixed at 33,000 foot-pounds per minute.

In proportioning steam machinery for any particular purpose, the first thing to settle upon is the amount of power required, and this being fixed in all cases, within certain limits, *the practical question is to obtain a certain power at the least possible cost.*

We will first discuss the ways and means used to measure and determine

The Power.

As has been said, the power of an engine depends upon the *work* done in a given time, and as work implies *force* and *motion*, we must ascertain three things before we can calculate the power, viz.: the *mean force* and the *distance* through which it is exerted, also the *time* required for the movement. Having these, we first ascertain the distance moved per minute, and this, multiplied by the mean force, gives the number of foot-pounds per minute, which divided by 33,000, gives the *horse-power*. The distance through which the force is exerted, is usually calculated from the number of revolutions made per minute by the engine, which can be ascertained approximately, by actual count, but better by means of a register. The speed of the engine is varied more or less by every change in the load, or in the pressure of steam, even when a governor is used; for a change in speed *must* take place before the governor can operate. The variations are small, with sensitive regulators, but in a majority of cases, would materially affect the result. The true plan, then, is to attach a register to the engine, the indications of which

should be taken once an hour, to check mistakes, and in the calculations the revolutions per minute should be an average for the whole time through which the trial extends. If the power is to be calculated from the pressure on the piston, the piston movement is also used and ascertained by multiplying the revolutions per minute by double the stroke of the engine (when the latter is double acting). When the tension of a belt or series of springs is to be used in calculating the power, the movement of each must also be found, and must be calculated from the speed of the engine. It will thus be seen that two elements of the *power* are easily ascertained, viz.: the *time* and the *distance* through which the force is exerted. The mean driving force is more difficult to obtain. There are two instruments in use for measuring this, viz.: the *indicator* and dynamometer. These two names are used in this paper in a restricted sense. The first is applied only to the well known steam engine indicator, and the latter to that form of dynamometer which is used to measure the force transmitted by revolving wheels or shafts.

It would be impossible, in the limits of this paper, to give a detailed description of the indicator. We therefore will mention only such features as are necessary to explain its mode of operation. The indicator is so constructed and attached that steam from the main cylinder presses upon one side of a small piston in the instrument, the atmosphere pressure being upon the other side. To the indicator piston is attached a spring and a pencil, the latter arranged to mark on paper. The predominating pressure on the indicator piston, whether of the steam or the atmosphere, extends or compresses the spring in proportion to the intensity of the pressure, and moves the pencil up and down on the paper. The paper is arranged on a drum, which is so connected that it has a side motion corresponding to that of the engine piston. Consequently, as the engine piston moves, the *paper* is moved *sideways*, and as the pressure changes, the *pencil* is correspondingly moved *up and down*, so that the figure or diagram, traced on the paper, is a combination of the two movements, and should show the pressure at each and all points of the stroke. The mean of a number of ordinates on the diagram, represents the mean pressure per square inch of piston, which multiplied by the area of the piston, gives the total face, which produces the piston movement, from which the power may be calculated, as has

been before explained. The indicator is a beautiful instrument, of such great value to the steam engine, that it may be said to deserve the numerous words that have been spoken in its praise. Still, in many cases, where it has hitherto been considered practically perfect, its indications are of the most deceitful and unreliable character. It shows very perfectly whether the valves are adjusted properly, and often when applied to an engine, which is working improperly, a mere glance at the diagram will reveal the difficulty, and suggest the remedy. Large leaks in the valves or piston may also be detected in this way. The indicated pressure at the end of the stroke has very often been employed to determine the quantity of steam used by the engine. Calculations founded on such a basis are entirely worthless, as will be explained, when treating of the cost of the power. It has often been attempted also to calculate the friction from the indicator-friction diagrams, but the system is practically erroneous, as will be explained hereafter.

The indicator is chiefly employed, however, to determine the power of an engine, it being supposed that the diagram shows correctly the pressure at all parts of the stroke. Even this it fails to do under certain circumstances. The moving parts of the instrument must have weight and friction, and some force is necessarily required to overcome the latter and put the mass in motion. If, therefore, the pressure be ascending, the indicator will show less than it should, and when the pressure is descending, the instrument will show more than it ought. In either case, then, the length of the ordinates is increased during any change of pressure, whence the mean pressure indicated is greater than actually existed in the cylinder. Until quite recently, we supposed that these inaccuracies were too small to require serious attention. Experiment has, however, proved the contrary. The Richard's or "parallel motion" Indicator is undoubtedly a great improvement upon the old style; but using one of the best of the first named instruments made by Elliot Brothers, of London, and carefully adjusted so as to move freely, but without shake in the joints, we have found inaccuracies in the diagrams of from 10 to 25 per cent. The results were so remarkable and unexpected that we propose to point out ready means whereby anybody may repeat the experiment. As has previously been explained, the weights and friction of the moving parts of the indicator cause the pencil to be somewhat tardy in re-

cording the *changes* of pressure, *hence the greater the extent or the rapidity of the changes, the greater should be the discrepancies.* If an engine be working full stroke, the steam and exhaust lines of the diagram will change so little that there will be *time* for the piston of the indicator to adjust itself to the pressure; the contrary will be the case, however, when the steam line is broken by expansion, or the exhaust line by extreme cushioning. The discrepancies would increase also with the speed of the engine. To test the amount of the variations, select an engine running at least 50 revolutions per minute, and provided with a good adjustable cut-off. Make arrangements so that the load of the engine will be as uniform as possible for a little while. Then cut off the steam in the cylinder as short as is possible to keep up a certain speed, then count and record the revolutions per minute, and take indicator diagrams for a short time. After this, without in any way altering the load, change the cut-off to full stroke as nearly as possible, and adjust the throttle so that the engine will make exactly the same speed as before, and again take indicator diagrams. The operations may be repeated several times to allow for inequalities in the load. The indicator diagrams taken under such circumstances, though of different shapes, should of course show the same mean pressure; for the engine was developing the same power in all cases. In practice, however, the cards taken with a short cut-off, will have a much greater area than the others, so that in fact the difference can be readily detected by the eye. We conclude, from our experience on the subject, that the indicator cannot be depended upon to accurately measure the power of high speed engines, working expansively. In many cases in practice, we suppose, however, that the discrepancies are so small that they may be disregarded. In marine practice, for instance, the paddle-engines run very slowly, and screw-engines do not generally work at a high degree of expansion; and in general, the power of all engines running slowly, or with little expansion, may be measured by the indicator with sufficient accuracy for general comparison. The difficulty occurs in cases like the locomotive or in stationary engines working very expansively, at a speed of from 50 to 200 revolutions per minute. In these cases, the indicator should be depended upon only in comparative tests, where the engines run at about the same speed, with about the same pressure of steam and degree of expansion. The stiffer the spring of the indicator, the lighter the moving parts, and the

smaller the range of the motion, the smaller will be the variations. Gooch's locomotive indicator seems to fulfil these requisites the best of any yet designed. The indicator is often applied to both steam and pump cylinders of pumping engines, when the difference in the power thus obtained shows the friction of the machinery.

The measurement of the power in the steam cylinder by the indicator is defective also, because it takes no account of the friction of the engine. If all engines of the same power, worked with substantially the same friction, this last consideration would be of little or no consequence. But a multiplicity of parts, awkward proportions, improper fittings, weak framing, &c., may cause some engines to have far greater friction than others. Again, questions as to the proper size and speed of an engine are influenced by friction. For instance, if a large engine is more economical than a small one, will not the gain be balanced by increased friction? The only way of settling these questions is by measuring the *nett power* of the engine, or that which *is available for useful work*. This can be done by the *dynamometer*. This instrument is made in many different forms. The friction dynamometer consists substantially, of half clamps, or boxes fitted to a revolving shaft, and kept from turning therewith by a lever held in position by weights and a spring balance. When in use, the clamps are tightened until they create sufficient friction to absorb the powers; the weights are then adjusted till they nearly balance. The amount of weight, the tension of the spring, and the speed of the shaft are then noted, when the power transmitted through the shaft may easily be calculated: for the force of the weight and spring is multiplied by the lever in proportion to its length, divided by the radius of the shaft, and this multiplied by the velocity of the bearing surface is — per minute, gives the foot-pounds. This form of dynamometer is little used, because it absorbs instead of transmitting the power. Besides, it is difficult, on a large scale, to maintain a constant friction for any length of time.

The dynamometers of greatest practical value transmit, and at the same time indicate the power, without in any way interfering with the regular duty of the engine. For instance, if the power be transmitted by means of a belt, and we can in any way measure the tension of the two parts, their difference represents a force moving with a given velocity, which may easily be reduced to units of power.

A dynamometer on this principle has been used abroad, which was re-invented by Horatio Allen, Esq., President of The Novelty Iron Works, in this city, and by him applied to the engines used in the U. S. Steam Expansion Experiments. In this case, the driving and driven shaft were separate, but lay in the same horizontal line. Near the contiguous ends, large wheels were placed with a **V** groove in the circumference of each. An endless rope passed in both directions, over the top of one wheel, then under side pulleys over the top of the other wheel. The side pulleys were below the centre of the large wheels, and were of such size that the four parts of the rope leading to them hung vertically. These pulleys ran in bearings free to slide vertically, and were connected to platforms carrying adjustable weights. The motion of the wheel, on the engine shaft, turned the other shaft in the opposite direction, by means of the rope, but tended, at the same time, to lift the side pulley. The opposite side pulley was weighted sufficiently to keep the rope from slipping, and weights and a small spring were adjusted on the driving side to balance the lifting force. Then half the difference in weight on the two side-wheels equalled the tension of the cord, or the driving force, which, together with the velocity of the cord, furnished the only elements necessary to calculate the power. This instrument had means attached to automatically record the strain on the cord, and answered its purpose very perfectly and satisfactorily. It was, however, too expensive and cumbersome for every-day use. Three beveled wheels, on the above principle, have been used as a governor, and would doubtless make a good dynamometer also.

Steel springs, properly arranged, form, we believe, the best dynamometer for practical use. As commonly constructed, a pulley, through which the power is transmitted, is made loose on the shaft and then is driven from it, through the intervention of springs; or one shaft is driven from another in the same manner. It is necessary, then, in order to calculate the power, to ascertain the tension of the springs, and their velocity where the force is applied. Neer's dynamometer, on this principle, may be taken as a type of its kind, and has given general satisfaction. The instrument must be attached in two places: one part to the driving shaft, and the other to the pulley or shaft to be driven; and the latter must not receive any motion except what is transmitted through the springs of the instrument. Secured to the instrument are two or more coiled steel

springs, lying in the same direction as the shaft. A chain passes through each spring, around a pulley, and from thence to a circular hub on the other shaft or pulley, to which hub the end of each chain is secured. Now if one shaft is moved, it tightens the chains and compresses the springs sufficiently to overcome the resistance and put the driving shaft or pulley in motion. The longitudinal motion of the springs moves a hand on a suitable dial, which is graduated so as to show the horse-power, when the shaft makes 100 revolutions per minute. The exact force is found by counting the speed of the shaft, and correcting the reading accordingly. The minor details of construction can best be explained by the manufacturers. The accuracy of an instrument of this kind can easily be tested by weighing the springs, measuring the distance from the centre at which they act, and correcting the dials accordingly.

(To be continued.)

ON THE EXPERIMENT OF LISSAJOUS.

By Prof. Edward C. Pickering.

In 1857, M. Lissajous studied the curves produced in the following experiment. Mirrors are attached to the prongs of two tuning forks, whose planes of vibration are at right angles to one another. A ray of light falling on the first, is reflected from it to the second, and is then projected on a screen by a lens. If, now, the fork which vibrates in a horizontal plane is sounded, the motion thus imparted to its mirror causes the luminous point on the screen to describe a horizontal line. Sounding the other fork in the same way, produces a vertical line. When both vibrate at the same time, various curves are produced, dependent on the relative pitch of the two forks.

When showing this experiment to an audience, it is desirable to have a set of curves, drawn on a large scale, for comparison. As, however, their geometrical construction is somewhat laborious, I have devised a machine, represented in the adjoining photo-lithograph, by which they may be drawn mechanically.

The paper on which the curves are drawn receives a horizontal motion to and fro, while, at the same time, the pen is moving vertically up and down. These motions are imparted thus:—Two

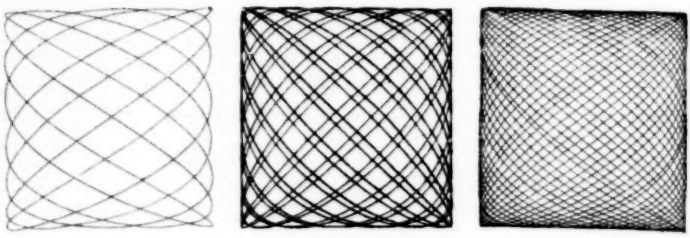
wheels (Fig. I.), connected by a belt, carry cranks, of which the lower one moves in a vertical slit in the rear of the square board to which the paper is attached. This board is kept in place below by a rod, over which it rolls, and above by a guide of sheet-brass. If, now, the lower wheel is turned, the paper moves horizontally through a distance equal to twice the crank-arm. A similar motion is imparted to the pen by a horizontal slit, in which the upper crank slides, and by which the pen is moved up and down. The rod is made flat to prevent its turning; or, it may be made circular, if we fix its slit in guides.

As a belt connects the two wheels, turning one moves both pen and paper. All the different phases of the curves corresponding to any given ratio of the number of vibrations of the two forks, may be drawn by merely sliding the belt over one of the wheels. As the ratio of the diameter of the latter corresponds to that of the number of vibrations of the forks, a series of wheels of different sizes are made, which, when combined two-and-two, give an almost endless variety of curves. Perhaps the best ratios, if we have four wheels, are $1 : 1\frac{1}{2} : 1\frac{3}{5} : 2$, by which we get curves corresponding to $\frac{16}{15}$, $\frac{5}{4}$, $\frac{4}{3}$, $\frac{3}{2}$, 2 and $\frac{8}{5}$, or to the semitone, major third, fourth, fifth, octave and minor sixth.

It may be proved that the curves coincide with those of Lissajous, since the angles described by the cranks are proportional to the diameter of the wheels; also, the distances of either pen or paper from the middle points of their paths are proportional to the sines of these angles. In other words, calling v the angle traversed by the upper crank, a, the ratio of the two wheels, and B, an angle dependent on the phase of the vibration, we have $y = \sin v$, and $x = (av + \text{B})$ equations defining Lissajous' curves.

To obtain curves corresponding to every ratio of the forks, expanding wheels may be used, in which, by turning a spiral guide, six sectors are made to approach or recede from the centre. With two such wheels, whose diameter can be altered from 3 to $4\frac{1}{4}$ inches, and from $4\frac{1}{4}$ to 6 inches, all the curves within the limits of an octave can be drawn. By a set screw the crank-arms may be shortened so that smaller curves may be drawn, also those inscribed in a rectangle instead of a square.

To draw the curves in ink, it was necessary to devise some new kind of pen. That represented in Fig. V*a*, answered as well as could be desired. It is easily made from a glass tube, by thicken-



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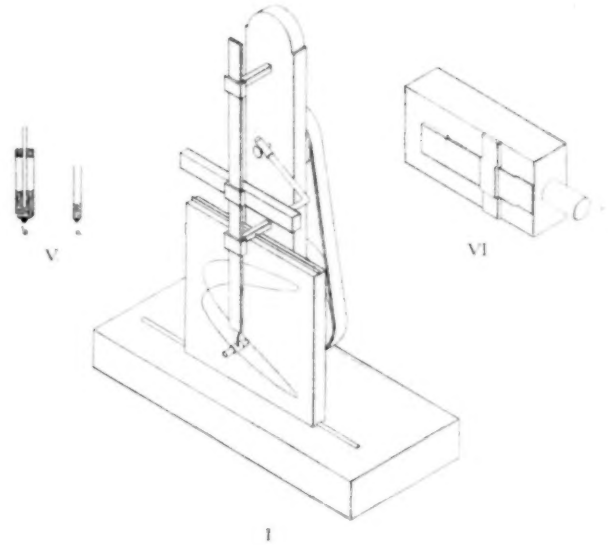


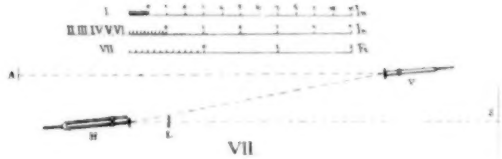
V VI

I

A Machine for Drawing

LISSAJOUS' VIBRATIONS.

EYE & PICKERING



VII

ing and nearly closing one end with the blowpipe, placing a drop of water in it, and grinding it flat on a file. When filled, the convex liquid surface at the small end retains the ink, while, when pressed on the paper, the flow takes place with great smoothness. Fig. V*b*, shows a modification which is useful for drawing diagrams. The pen is made so as to contain a large supply of ink, which is kept from running out by closing one end by a cork, through which passes a tube, as in the figure. The pressure is then constant, and equals that of a column whose height is the distance from the point of the pen to the end of the inner tube. By varying this distance, we can use a high pressure for thick ink, and a low pressure for that which is more fluid.

In Figs. II., III. and IV., are given specimens of curves drawn by the apparatus above described, to show its practical working. In Fig. II., the ratio is 5 to 8, or the curve of the minor sixth; in Fig. III. it is 15 to 16, or a semitone; and in Fig. IV. about 3: 4, more nearly 44: 59, or a sharp fourth. In the latter case the curve does not close exactly, since the ratio is incommensurable. As these curves are here reproduced by photography, the slightest errors are visible, and they furnish a good test of the workmanship of the machine. Probably still greater accuracy would have been attained had the apparatus by which they were drawn been constructed by a professional instrument-maker.

When projecting the curves of Lissajous it is somewhat difficult to show the more complicated forms, owing to the large size of the luminous point compared with the curves themselves. I find the arrangement of Fig. VII. gives the best results. A is an aperture through which a ray of sunlight enters; V and H are the two forks, one vibrating in a vertical, the other in a horizontal plane; L is a lens of 6 feet focus, by which the curve is projected on the screen, S. The size of the curve depends only on the distance, L S, or on H S, if the light traverses the lens before meeting the mirror, H, and, therefore, the lens must be brought near the aperature, A. But, if we use a lens of short focal length, the luminous point is greatly magnified, since its diameter is proportional to $\frac{\text{L S}}{\text{A V} + \text{V H} + \text{H S}}$. I therefore use a lens of 6 feet focus, and remove V to a distance of $3\frac{1}{2}$ feet from H, so that A V + V H + H L and L S shall be conjugate foci. This would be the case in Fig. VII., when L S is 18 feet, or in a room

20 feet wide. It is not represented in its true size, in the figure, for want of space.

Lenses suitable for these projections of any size not exceeding 8 inches in diameter, and 6 feet focus, may be obtained at a low price from the makers of cosmoramas. Although not achromatic, their aberration is exceedingly small, from their great focal length. They are useful for many purposes, particularly in large lecture-rooms; thus, in projecting the solar spectrum, I find them preferable to much more expensive achromatic lenses of short focal length. Again, by using one as an object-glass, a very good telescope for class purposes may be made for a few dollars, capable of showing all the more familiar astronomical objects, such as satellites of Jupiter, ring of Saturn, prominent nebulæ, &c., and which would, I think, be of great use to many institutions where a more expensive instrument could not be afforded.

Fig. VII. represents a substitute for the tuning forks in the experiment of Lissajous. It consists of a rectangular box, in which is an aperture just filled by a square plate, carrying the mirror. This is attached to an elastic strip of metal, which vibrates when air is forced into the box, like the tongue of a melodeon-reed. To vary the rapidity of vibration, the metal strip or tongue passes through a guide, by which means its length may be altered, and this may be done with the utmost precision by a screw not represented in the figure. This adjustment is not necessary in the reed replacing the second tuning fork, since a range of more than an octave is readily obtained by the method here described. The advantages claimed for this apparatus over the tuning forks are, that the angular amplitude is much greater, hence the curves on the screen are of very large size; that they may be maintained indefinitely by keeping up the supply by the bellows, and most important of all, by merely turning the screw, the progressive changes of one curve into another may be shown, so that, in a few moments, all possible combinations may be exhibited.

My experiments with this apparatus are not yet completed, as I find that the vibrating part must be made with a good deal of care, or the curve will not be perfect. In fact, in a preliminary experiment, in which I used too feeble a spring, I found that it answered admirably for showing the difference of quality of different sounds. By touching the mirror with the point of a knife, so as to produce a rattling noise, I obtained, with a single reed, instead of a right line, a complicated curve, which varied with every change in the sound.

ANTI-FRICTION ROLLS AND CAGES FOR SHEAVES.

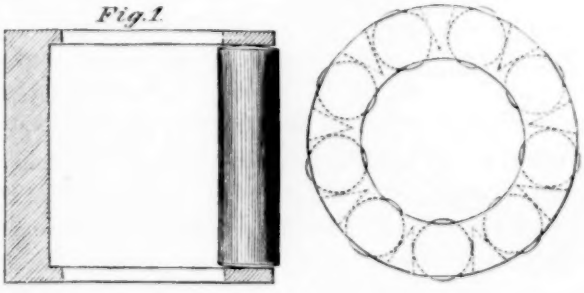
By J. H. Cooper.

In Gregory's treatise on Mechanics, published in London, in 1806, mention is made of Garnet's anti-friction rolls, which consist of a series of rolls arranged parallel to and around about a shaft or pin, each roll having journals fitted in end rings, which latter are secured together, forming a rigid cage for all to revolve in, free from contact with one another, and for preserving their parallelism with the shaft. This appears to be the usual plan of making anti-friction rolls and cages, as it is the oldest, and has the merit of allowing the greatest number of rolls in the circle, as they are placed as closely as possible without touching, but are open to the objection of weakness in the cages from lack of room between the rolls for securing the rings, unless, as is sometimes done, every second or third, or fourth roll, is drilled through for connecting studs to the opposite rings, which answer also for journals for the tubular rolls thus made.

This plan strengthens the cage, but renders the tubular rolls liable to collapse under heavy pressure.

Another old plan, which is probably the simplest, as well as the cheapest to manufacture, consists of solid rolls without journals

Fig. 1.



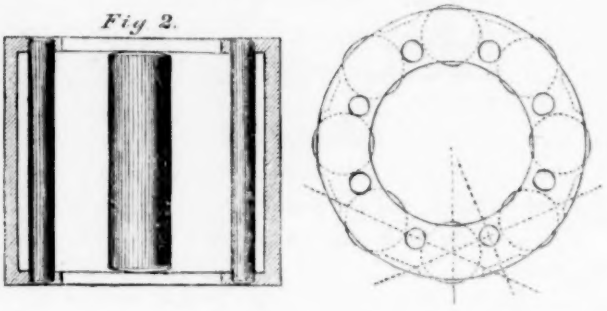
placed in stalls formed by the connecting bars of the end rings, which are cast in one piece with the latter. The proper shape of the stalls is that in which the opposite sides are parallel planes, as shown in Fig. 1.

In Fig. 2, a different system of anti-friction rolls is shown, which

we have devised for the purpose of gaining a better use of this ingenious and useful mechanism.

In this, the rolls are all solid, and are without journals, the bear-

Fig 2.



ing rolls being separated by smaller ones, terminating in the end rings. These smaller rolls have slotted bearings, which allow for slight displacement of the larger rolls, resulting from wear, they occupy a position in the system on a line joining the centres of two contiguous rolls, and have such a diameter as will give them sufficient strength, and cause all the rolls to touch one another when working.

The end rings are united in one piece by bars cast with them, occupying the interspaces of the larger rolls, and outside of the smaller ones, but not in contact with either, thus making a comparatively cheap and rigid cage.

In this anti-friction device, the *contact is all rolling*, and must, in consequence, not only have a minimum of friction, but of wear also.

We have a number of rolls made after this system, in use in the sheaves of cranes, which are subjected to the severe usage of steam power in a pipe foundry, and know them to operate freely and well, and to promise fairly for continuance in good service.

Philadelphia, November, 1868.

EDUCATIONAL

LECTURES ON VENTILATION.

By Lewis W. Leeds.

Second Course, delivered before the Franklin Institute, during the winter of 1867-68.

(Continued from page 424, Vol. LVI.)

From the crude facts that have been thus gathered, we are led to suppose that the proportion of carbonic acid in the exhaled breath, varies greatly under many different circumstances.

Temperature has a very great effect. Experiments have been tried with birds and animals, showing that there is less than one-half exhaled when breathing a temperature of from 86° to 106°, than there is when breathing air at a temperature near the freezing point.

The *proportion* of carbonic acid contained in the exhaled air varies greatly, as also does the aggregate amount; it constitutes from 3 to 8 per cent. of the volume exhaled—probably 4 or 5 per cent. would be the proper average. Hence, as pure air (so called), seldom contains more than five parts of the gas in ten thousand, it follows that the breath contains one hundred times the natural quantity found in the atmosphere.

That jar, therefore, contains about one hundred times as much of this poisonous deadly gas, as does pure air, and not only that, there are particles of my body, there are portions of my brain (I don't mean in the sense in which we use it to express the result of thought), but I mean the actual worn-out material; and the only valuable substance it originally contained—the oxygen—has been taken out. It is upon the whole a very disgusting mass, as you must admit, and we will remove it carefully, so as not to permit it to escape into this room. I perceive you seem a little amused. I suppose it is at the idea of carrying out that one jar of foul air such as we are all the time exhaling into the same air we *inhale* from; but I think this gives you the true idea of ventilation.

The actual amount of air breathed is comparatively very small; it is only about the one-fourth of one cubic foot per minute. But it is the contamination of the remaining mass that causes the trouble. For instance, as the exhaled breath contains one hundred times as much carbonic acid as pure air does, hence, if one cubic foot of breath was diffused through one hundred cubic feet of air, it would add, even to that very large amount, nearly double its normal quantity.

In determining what amount of fresh air must be supplied for each individual, in a room in which we are each breathing into and from the same general mass, it becomes a question of what proportion of other persons breath we are *willing* to take into our own lungs. If we breathe but the one-fourth of one foot per minute, a supply of twenty-five cubic feet per minute would give us one hundred times the actual amount of air that passes through the lungs, so that we should then only have to breathe double the normal quantity of carbonic acid.

This twenty-five feet per person per minute, however, is considered by many a large allowance. As low as ten cubic feet per minute for each person is considered by others to be a sufficient quantity, yet even that is much more than vast numbers of our buildings are supplied with, as may be readily judged from the disgusting foul odors noticed in many of them, and which could scarcely ever be perceived if this small allowance even was carefully furnished. Of excretions from the surface of the body in the form of insensible perspiration, which are constantly occurring, I have as yet made no allusion.

But now suppose that instead of discharging the breath into the general reservoir, we could discharge it into a closed vessel, as we have done, or by a speaking-tube—if I might so term it—or better, a *breathing* tube, directly into a foul air duct, to be carried entirely out of the building; don't you see that one-tenth part of the air that would otherwise be required, would in that case be entirely sufficient? It would then be certainly much preferable to our present arrangements, because we should have radically *pure air*, instead of at best, that which was slightly contaminated.

I don't exactly mean to advise that we should each one carry a long breathing tube in his pocket, and the moment he came into the house, place one end in the fire-place, and put the other in his mouth before he began to talk to you; but I think it demonstrates

the true principle upon which we should act, in making our arrangements for ventilation, which is to say—to confine the polluted air—and to remove it as soon as possible from the room. I design showing you in a subsequent lecture that this has been my guide, in the arrangements for ventilations in hospitals, churches, schools, etc. and which I may add have been very successful.

It is a curiously interesting fact, that the temperature of the body remains nearly uniform at 98°, under the most extreme variations of external temperature, say from 40° to 60°, below zero, as experienced by Arctic voyagers, to a temperature of from 200° to 300° *above*, experienced by persons accustomed to entering and remaining for some time in furnaces for baking certain wares, and in like employments.

The cooling off, when we are very warm, is caused by the vaporization of the perspiration. A pint of water makes 1,700 pints of steam, but as it turns into vapor, or is enlarged like the expansion of a sponge, it absorbs heat very rapidly. Thus, when you perspire freely, or when you see the vapor arising from a hard-worked animal, you may know that the heat is being conducted away rapidly. It is for this reason that the drinking of a cup of hot tea on a warm summer day, by inducing profuse perspiration, has such a cooling and refreshing effect.

But this very fact of profuse perspiration, is frequently the cause of what we term "colds;" because, when we are perspiring thus freely from active exercise, and the heat is escaping very rapidly from the body, we are apt, when we have an opportunity to rest, to indulge in the agreeable process of "cooling off," wherein the temperature of the body is reduced so much more rapidly than in its ordinary conditions, that almost before we are aware, it is quite below the usual temperature of health. And so it happens that the relaxation of the respiratory organs, and the cessation of the rapid flow of blood, prevents the quick renewal of the heat; or in other words, the fires having been put out by the profuse perspiration, it requires a long time for them to be rekindled, and to get to burning again freely.

There are said to be 2,800 little tubes for the escape of the perspiration, in every square inch of one's body, and that the united length of all those in the skin of a single person, is about twenty-eight miles; so that the length of those in *two* persons, would reach from here nearly to the Atlantic Ocean. Now, the little valves at

the outer ends of these tubes, close very quickly on being exposed to the cold. But as the flow of the current from the interior of the body, does not feel the effects of the cold as suddenly as the valves, it will continue to press forward with its load of impurities, until, being checked from escaping, it will be dammed up near the ordinary places of exit, causing a pressure or inflammation.

To show what powerful effects may be looked for by this sudden stoppage of perspiration, we need only to adduce the fact of the large amounts of moisture which may be driven from the body through the medium of these channels of the skin. A number of experiments tried by Dr. Southwood Smith, on the men working in the Phœnix Gas Works, showed that the average loss of weight per man while charging the furnace or during an exercise of about fifty minutes, was something like three pounds. Just think what an inflammatory effect this enormous pressure, this sudden restraining of the great flow of impure moisture, must produce!

And it is not on the *external* surface only, that this result is produced, but the lining membrane of the air-passages to the lungs is affected even more suddenly, and is also more sensitive than any other. Therefore, we should always remember that the moment we diminish any active exercise, we should immediately, even while much heated, put on an additional garment, or otherwise provide for a very gradual cooling off; being careful that we first cool off *internally*, before allowing the temperature of the external surface to be much lowered.

The manner of taking cold on leaving a crowded and badly ventilated room, is quite different.

You remember the experiment with the flies that lived ten times as long in the foul air we breathe, as did those in the pure air, and which we attributed to the very sluggish action of all their living functions. Now, when you leave a hot, foul room, although your perspiratory glands may be fully open, and there may be a rapid vaporization from the surface of the body and the air-passages to the lungs, which would not be caused by exercise in this case, but, worse, by the heat of the room, yet the vitiated air that you have been breathing, has not only choked up your lungs and filled your body with the actual presence of much poisonous material, but it has so reduced the circulation that you cannot get up a reaction.

As in one minute after you have emerged into the pure air, you have breathed twenty times, or inhaled 400 cubic inches, the lungs

therefore, are the parts most quickly affected. You will frequently feel the inflammation thus produced in your throat, in five or ten minutes after leaving such a room; but you must remember that in ten minutes you will have breathed 4,000 cubic inches of cold air. To leave a room such as I have spoken of, and, in place of walking, to sit down in a cold, crowded, foul car, with your back towards the window, is one of the very best possible means, not only of taking cold, but of contracting any other disease to which you may possibly be subject.

(To be continued.)

SUNLIGHT AND MOONLIGHT.

A Lecture delivered at the Academy of Music, before the Franklin Institute, on May 23d and June 6th, 1868.

By Prof. Henry Morton, Ph. D.

(Continued from p. 418, Vol. LVI.)

We will now pass from the subject of reflected to that of originally emitted or developed light—from the Moon to the Sun.

The most perspicuous method of treating this subject will be to explain, in the first place, one of the most probable among the modern theories of the constitution of the Sun, and then to exhibit the various facts or phenomena on which the theory is based, and from which it receives its support.

We believe that the Sun consists of a dense central mass, composed of only the most refractory materials, intensely hot, and probably fluid, at its surface at least, with heat. From this supernatant ocean of melted matter, rise, continually, streams of vapor, which, at a certain distance, begin to condense, through loss of a part of their heat by radiation into space, and form clouds of minute liquid particles, intensely hot, and therefore luminous in a high degree.

These clouds form the visible surface or photoscope of the Sun, and are composed of such elements only as will endure an intense heat without vaporizing. Above this cloud region, extends another, which may be called the true atmosphere of the Sun, being composed of such elements as are permanently gaseous under the conditions of high temperature there existing. Such substances as

Sodium, Magnesium, Calcium, Iron, are believed to exist as permanent vapors in this region, as well as Hydrogen and other gases. Into this region are occasionally projected denser aggregations of similar vapors, as of Sodium, Magnesium and Iron, which float, for a time, as clouds of ignited gas, before diffusing among the surrounding mixed atmosphere.

Figure 1, in the accompanying plate, will give some general idea of this arrangement of parts or regions. While Figure 2 will convey some notion of the detail implied in part of this action, this drawing being intended to represent a view at the surface of the Sun, showing the molten ocean, the uprushing streams of vapor, the cloud-caps at their heads, and the in-rushing meteorites, to be presently noticed.

These clouds, it may be here remarked, are, on the average, about 1,000 miles broad each, which shows us that here, as in our lunar landscapes, we are dealing with distances which it is far easier to name than to imagine.

As a cause and supplying source of this intense heat which we have here assumed, we believe there exists the following action: The space of the solar system is filled with a vast number of ponderable objects, individually minute, but, in the aggregate, considerable. Some of these, from time to time, fall upon our planet, and are then called Meteors; they are, however, much more densely aggregated as they approach the Sun, and, by mutual interference and disturbance, will be constantly losing their orbitual directions, and, under the influence of gravity, falling in upon the solar mass.

The velocity which bodies would acquire in free space, under the influence of the Sun's attraction, is easy to calculate, and would be, under different assumptions as to original distance, &c, included between the limits of 60 and 85 miles per second.

We know what happens to a rapidly-moving body when its motion is arrested by some obstacle—it becomes heated. Thus a hammer-face is hot after striking a dozen blows; and a cannon-ball, arrested by an iron target, becomes almost red-hot; so a flint strikes off particles of steel, and ignites them by its arrested motion. But if *these* motions and velocities do so much, what must such as we have named develop? A cannon-ball has a velocity of 1,500 feet per second, or about one-third of a mile; it almost grows red-hot by its own impact; what heat would it develop if its velocity

were 60 or 80 miles—that is, 180 to 255 times as great? We can readily calculate this, and find that the heat which any mass would so develop by its blow, would be from 4,600 to 9,200 times as great as if it were a mass of coal consumed in oxygen.

We see, then, that this impact of falling bodies, under the existing conditions of the question, would be a far more plentiful source of heat than any other which we could suggest; but it may yet be asked, What evidence have we that such masses of matter are in existence, and are rolling in upon the Sun?

The zodiacal light is the first proof of this supposition.

In the evenings of March and April, in this latitude, when twilight is of shortest duration, we may see, to the west, after sunset, a conical mass of light rising into the sky. This is the zodiacal light. And, again, in September and October, before sunrise, a similar appearance is observed. As we approach the equator, where, as we know, the twilight is always brief, the zodiacal light becomes more distinct, and visible throughout the year, on clear nights; it is also more vertical, and appears, in fact, to lie in the plane of the ecliptic.

The most natural hypothesis as to the cause of this appearance is, that there are here shown to us a cloud of minute bodies revolving around the sun, illuminated by his light. Variations in the apparent magnitude and intensity of the zodiacal light, point to changes in the conformation of this swarm of minute planets, such as we cannot but anticipate from their individual minuteness and close juxtaposition; and agree entirely with the supposition that part of them are, from time to time, falling in upon the Sun, and that they are also receiving supplies from the exterior space, as we shall next see, for the next proof of the supposed origin of solar heat is furnished by the *Meteors*. We need not here explain what is meant by a meteorærolite, or falling star; there can hardly be a person present who has not seen many of them; suffice it to say, that there is no shadow of doubt that these are small bodies of matter which, moving through space, either encounter our atmosphere alone, and flying through it at vast velocities, are heated to ignition by the resistance it offers, or running against the solid mass of the earth, are arrested as well as heated by the encounter.

By a careful observation of the velocities and directions of these bodies, when thus momentarily exhibited to us, as well as the times of their appearance, and the position of the earth in her

orbit, at such times, it has been proved that there are a great number of streams, rings, or elongated cosmical clouds of such bodies sweeping in, to and around the Sun, from all parts of space. Through these streams the earth passes at certain seasons, and we then see a shower of shooting stars, while at all other times we can have no knowledge of their presence, except so far as some of them may be combined with, and add to, the luminosity of the zodiacal light.

It would appear from the observations of Schiaparelli and Newton, as well as of others who have given attention to Meteoric Astronomy, that the earth's orbit intersects at least thirteen of these streams, among which, some, as that of the November Meteors, are well-defined and fully known as to the limits of their orbits, rate of motion, extent and date of first entrance into the solar system, &c.*

Other groups are of a more irregular description, and may, indeed, be regarded as being *cosmical rivers* of the scattered matter left unaccumulated on the boundary-line between great attractive centres, in the original formation of suns or stars, from the nebulous condition of the universe; and as afterwards drawn down towards some preponderating centre, but dragged out into a long trail, displaced, bent and twisted by the attraction of planetary or other masses, and so sweeping in towards and around the Sun, in sinuous lines, in which condition from their vast length, centuries may be occupied in their passing any one point.

The mutual interferences in motion, and consequent in-fall upon the Sun, of masses so grouped and thus moving, must be constant: and, indeed, in at least one remarkable case, we have palpable evidence of such an action. In December, of 1845, Biela's comet was seen to be divided in two, and, on the date of its calculated return, in 1865, it had disappeared entirely. Now, at each of these periods the comet appears to have passed through the orbit of the Meteors of November 27th, whose direction of motion is retrograde, while that of the comet is direct; and it would thus seem that the resistance offered by the innumerable minute particles of the meteoric stream, had first divided the comet, and then caused it, together, no doubt, with these conquering atoms, to fall into the Sun.

* For a full account of these subjects, we would refer to this *Journal*, Vol. LIV., p. 14, or to Professor Kirkwood's excellent little book on Meteoric Astronomy, published by J. B. Lippincott, of this city.

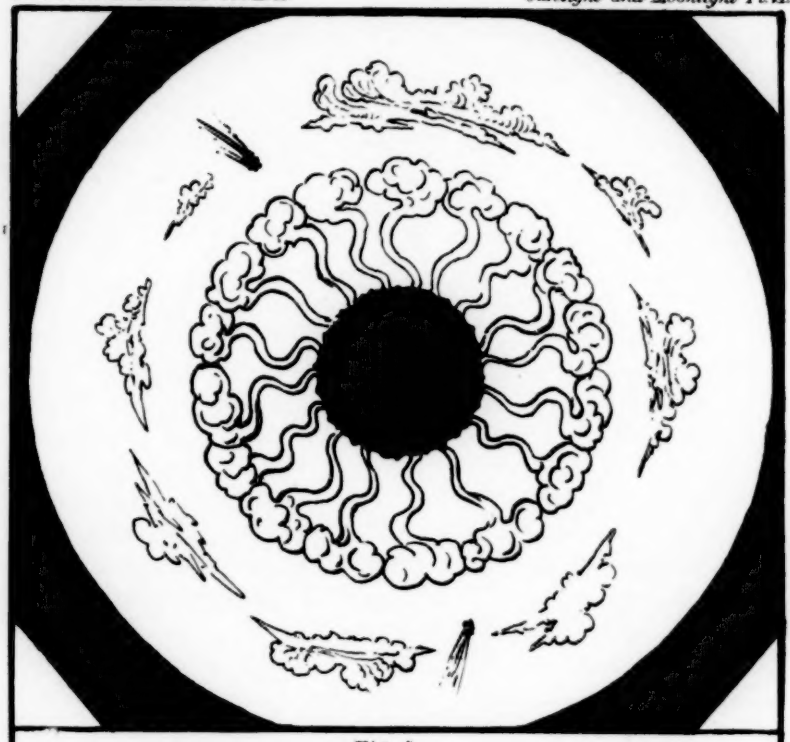


Fig 1.

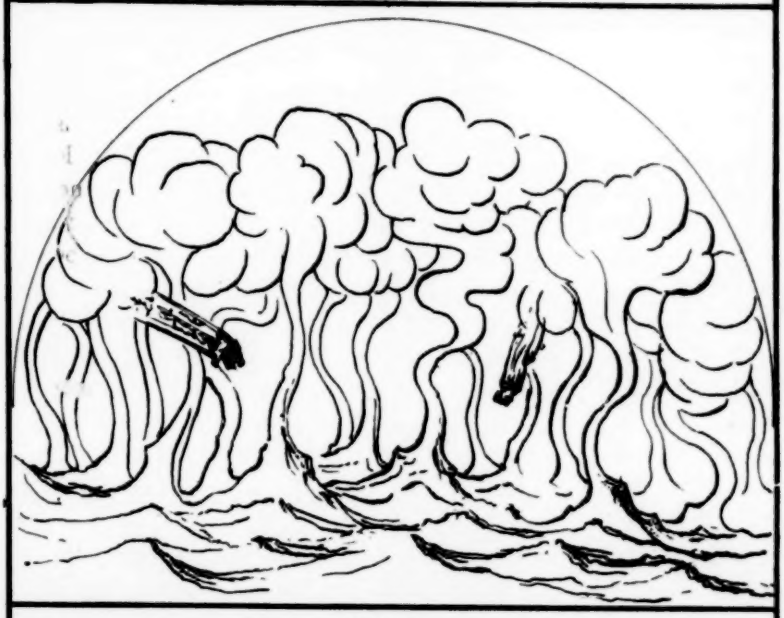


Fig 2.

We thus see that such a supply of matter as would be required to maintain the Sun's stock of heat, enormous as is his expenditure, is at hand.

(To be continued.)

Franklin Institute.

Proceedings of the Stated Monthly Meeting, November 18th, 1868.

THE meeting was called to order with the Vice-President, Mr. Coleman Sellers, in the chair.

The minutes of the last meeting were read and approved.

The Actuary submitted the minutes of the Board of Managers, and reported the donations to the Library received at the stated meeting, held November, 11th inst.: from the Royal Astronomical Society, the Statistical Society, and the Chemical Society, London, England; la Société Industrielle, Mulhouse, France; der Osterreichen Ingenieur-veriens, Vienna, Austria; the Board of Public Works, Chicago, Illinois; the Louisville and Nashville Railroad Company, Louisville, Kentucky; Charles H. Hart, Esq., Professor J. Aitkin Meigs, and Hector Orr, Esq., Philadelphia.

The various Standing Committees reported their minutes.

The Secretary's report on Novelties in Science and Arts was then read.

Remarks were then made by Mr. Coleman Sellers, on the subject of the Huntoon Governor; by Prof. Robt. C. Rogers, on the Manufacture of Ruhmkorff Coils and Geissler Tubes, by M. Gaiffe; and on the New Theory of Puddling, by Mr. Robert Briggs, after this the meeting, on motion, adjourned.

HENRY MORTON, *Secretary.*

Bibliographical Notices.

London Chemical News. American reprint. W. A. Townsend & Adams, 434 Broome Street, New York.

In the number of this publication for December, which we have just received, we observe that a new feature has been introduced, in the shape of a supplement, under the editorial charge of Professor Charles A Seely, which contains notices of the current events in America relating to the progress of Chemistry and the Physical Sciences; also, reviews of new books, notices of the market, and movements of trade, bearing upon the same subjects. It would be unnecessary for us to comment upon the excellence and value of the *Chemical News*, which owes its existence and success to the ability and untiring energy of Dr. Crookes, on whom it reflects, by its well-merited success, no small credit. We are glad, for the credit of our country, that the American reprint is made with the approval of, and by arrangement with, the English editor, and cordially commend it to our readers as a journal of unequalled value in its own department, and in all respects worthy of their support.

Its columns are freely opened to writers on this side of the Atlantic, and their communications are treated with courtesy and respect. We observe the names of some of our most eminent chemists among its contributors; and it is, of course, the organ of all distinguished students in this branch abroad, and no follower of this youngest but most important of the sciences, should think his laboratory furnished without a set of this journal.

Physicians' Medical Compend and Pharmaceutical Formulæ. Compiled by Edward H. Hance. Published by Hance, Griffith & Co., Philadelphia.

This little pocket-book, of 214 pages, filled with recipes and memoranda such as would be required by the physician or apothecary when making up or dispensing medicines, as also a full list of poisons, with their antidotes and treatments, and a full index, seems to us to be a very useful addition to the well-stocked armory of weapons with which modern science fights disease. We are not in a position to speak of its accuracy, but, since it is a compilation, it is fair to presume that the best authorities have been accurately followed, which is all that could be asked in such a case.

A COMPARISON *of some of the Meteorological Phenomena of* NOVEMBER, 1868, *with those of* NOVEMBER, 1867, *and of the same month for* EIGHTEEN *years, at Philadelphia, Pa.* Barometer 60 feet above mean tide in the Delaware River. Latitude 39° 57½′ N.; Longitude 75° 11¼′ W. from Greenwich. By JAMES A. KIRKPATRICK, A. M.

	November, 1868.	November, 1867.	November, for 18 years.
Thermometer—Highest—degree.....	72·00°	69·00°	80·00°
" date.....	10th.	9th.	1st, '60.
Warmest day—mean ..	62·33	62·33	72·30
" " date.....	9th.	9th.	9th, '57.
Lowest—degree.....	33·00	24·00	16·60
" date.....	23d.	19th.	25th, '60.
Coldest day—mean	37·33	31·00	23·30
" " date	22d.	18th & 19th.	25th, '60.
Mean daily oscillation...	12·10	14·47	13·20
" " range.....	5·37	6·37	5·68
Means at 7 A. M.....	42·38	42·93	41·46
" 2 P. M.....	50·30	51·33	50·42
" 9 P. M.....	45·02	46·68	44·71
" for the month....	45·90	46·98	45·53
Barometer—Highest—inches.....	30·418	30·342	30·661
" date.....	13th.	5th.	12th, '51.
Greatest mean daily pressure	30·369	30·325	30·520
" " " date...	7th.	5th.	12th, '51.
Lowest—inches	29·355	29·250	29·080
" date.....	30th.	29th.	4th, '64.
Least mean daily pressure...	29·426	29·593	29·150
" " " date...	30th.	29th.	4th, '64.
Mean daily range.....	0·187	0·182	0·183
Means at 7 A. M	30·005	30·006	29·920
" 2 P. M	29·963	29·972	29·876
" 9 P. M	29·992	29·994	29·906
" for the month	29·987	29·991	29·901
Force of Vapor—Greatest—inches	0·486	0·548	0·832
" date	10th.	10th.	8th, '57.
Least—inches.....	·104	·100	·055
" date.....	12th.	18th.	25th, '57.
Means at 7 A. M.....	·212	·236	·223
" 2 P. M.....	·201	·256	·228
" 9 P. M.....	·217	·258	·233
" for the month...	·210	·250	·228
Relative Humidity—Greatest—per cent	93·0	94·0	100·0
" date.....	18th.	10th.	Often.
Least—per cent....	36·0	41·0	25·0
" date.....	12th.	16th.	7, '63 & 25, '66
Means at 7 A. M....	75·3	80·03	77·1
" 2 P. M....	52·6	63·0	58·4
" 9 P. M....	70·5	76·5	73·2
" for the month	66·1	73·3	69·6
Clouds—Number of clear days*.	9·	8·	8·6
" cloudy days	21·	22·	21·4
Means of sky covered at 7 A. M	61·7 per ct	65·0 per ct	60·7 per ct
" " " 2 P. M	55·0	66·0	60·3
" " " 9 P. M	44·0	50·0	51·4
" " for the month	53·5	60·3	57·5
Rain—Amount—inches	4·53	2·540	3·613
No. of days on which rain fell	9·	10·	10·1
Prevailing Winds—Times in 100).....	N70°21′W.258	S76°32′W.261	S74°32′W.256

* Sky one-third or less covered at the hours of observation